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THE SEWAGE PROBLEM.

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SEWAGE PROBLEM:

A Review

OF

THE EVIDENCE COLLECTED

BY THE

Royal Commission on Sewage Disposal.

BY

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PREFACE.

The Royal Commission on Sewage Disposal has now entered upon its seventh year. Since its appointment, on 7th May, 1898, it has examined a large number of witnesses, visited many sewage works of various kinds throughout the country, and has instituted through its own officers a number of important scientific investigations. It has issued four Reports, comprising, with the evidence and accompanying Reports by the Officers of the Commission, fourteen Volumes in all.*

Great as is the work already accomplished, much remains to be done. The Commissioners in their last Reports indicate some of the investigations which have yet to be completed.

When the Commission was appointed, hopes were entertained in many quarters, especially by Local Authorities, many of whom were, at the time, in a position of the gravest difficulty with respect to their sewage, that the Commissioners would see their way to issue an early Report which should sweep away the anomalies and hindrances by which the question of sewage disposal was surrounded. To such the

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* A complete list of the Commissioners' Reports is given in Appendix B.

delay in the issue of a final Report has doubtless occasioned keen disappointment. At the same time, none can fail to recognise the ability and determination with which the Commissioners have addressed themselves to the solution of the weighty questions submitted to them, or the value of the Reports which they have already issued.

To those who are engaged in the practical work of sewage disposal, and who find themselves confronted from day to day by problems for the solution of which the experience as yet to hand is all too scanty, the Second Volumes of the First and Third Reports, containing as they do the evidence of many of the ablest and most experienced workers in this field, are particularly helpful. From the necessities of the case, however, the various branches of the subject could not be followed up consecutively, but had to be dropped and resumed as successive witnesses presented themselves for examination. The same subject matter therefore comes up a score of times or more in the course of the 16,297 questions and answers of which the evidence is made up, and in spite of the copious Indexes it is by no means easy to follow the thread of it in and out through the 821 pages of the two Volumes.

The writer has therefore attempted in the following Chapters a Digest of the more important evidence on some of the practical points which are dealt with. In so doing his object has been to let the witnesses as far as possible speak for themselves. He has not, however, confined himself strictly to the two Volumes of evidence, but has drawn also upon the

other Volumes, and to a limited extent upon outside sources, for information which seemed to throw light on the matters under consideration.

It is impossible within the compass of this Book to give even an outline of all the subjects into which the Commissioners have enquired, or to convey any adequate impression of the exhaustive manner in which they have been treated. The writer has therefore contented himself with the endeavour to indicate the general trend of the Commissioners' investigations, and to bring together in a concise form some of the evidence which they have collected with regard to certain practical questions, the information concerning which has hitherto been both scanty and disconnected.

He gratefully acknowledges the valuable help which he has received from his father, Mr. J. M. Martin, particularly in the revision of the proofs.

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APPENDIX B.

THE SEWAGE PROBLEM.

CHAPTER I.

INTRODUCTORY.

The Commission now sitting is far from being the first which has been appointed to report on the subject of sewage disposal. A detailed history of the question in all its varying phases would occupy many volumes, but a comprehensive view of the sequence of events, more particularly those which led up to the issue of the present Commission, may be obtained from the brief chronological summary which forms Appendix A.

The Commissioners originally appointed to conduct the present inquiry were :—

The Right Hon. the Earl of Iddesleigh, C.B. (Chairman of the Inland Revenue Board).

Sir Richard Thorne Thorne, K.C.B., F.R.S. (Medical Officer of the Local Government Board for England).

Major-General Constantine Phipps Carey, R.E. (Chief Engineering Inspector of the Local Government Board for England).

Charles Philip Cotton, Esq., M.Inst.C.E. (Chief Engineering Inspector of the Local Government Board for Ireland).

Michael Foster, Esq., D.C.L., D.Sc., LL.D., F.R.S. (Professor of Physiology in the University of Cambridge, M.P. for London University, now K.C.B.).

Colonel Thomas Walter Harding, M.I.M.E. (Alderman, and Chairman of the Sewerage Committee of the Leeds City Council).

COMMISSIONERS APPOINTED—*continued.*

THOMAS WILLIAM KILLICK, Esq. (Chairman of the Consulting Sub-Committee of the Mersey and Irwell Joint Committee).

WILLIAM RAMSAY, Esq., LL.D., D.Sc., Ph.D., F.R.S. (Professor of Chemistry, University College, London, now K.C.B.).

JAMES BURN RUSSELL, Esq., M.D., M.S., LL.D. (Medical Officer of Health for Glasgow, since appointed Medical Member of the Local Government Board for Scotland).

The Commission has lost three of its members by the death of Sir Richard Thorne Thorne, and the retirement of Mr. Killick and Mr. Cotton. Sir Richard Thorne Thorne's place on the Commission was filled on 7th February, 1900, by the appointment of Dr. WILLIAM HENRY POWER, F.R.S., his successor as Medical Officer of the Local Government Board; and on 7th May, 1902, Dr. THOMAS JOSEPH STAFFORD, F.R.C.S.I., Medical Commissioner of the Local Government Board for Ireland, took that vacated by Mr. Cotton.

Mr. FREDERICK JAMES WILLIS, of the clerical staff of the English Local Government Board, was appointed by the Warrant Secretary to the Commission, and the Commissioners themselves subsequently appointed the following officers:—

Professor BOYCE and Dr. HOUSTON, Bacteriologists.

Dr. McGOWAN and Mr. COLIN FRYE, Chemists; and

Mr. G. B. KERSHAW, Engineer.

TERMS OF REFERENCE.

Tho duties assigned to the Commission, as set forth in the warrant, are—

"To inquire and report:

"1.—(1) What method or methods of treating and disposing of sewage (including any liquid from any factory or manufacturing process) may properly be adopted, consistently with due regard for the requirements of the existing law, for the protection of public health, and for the economi-

cal and efficient discharge of the duties of local authorities; and

"(2) If more than one method may be adopted, by what rules, in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, should the particular method of treatment and disposal to be adopted be determined; and

"2. To make any recommendations which may be deemed desirable with reference to the treatment and disposal of sewage."

The Commissioners lost no time in getting to work, but more than three years passed by before the first fruits of their labours saw the light.

Interim Report, 1901.

On 12th July, 1901, they made a preliminary report, in tho opening paragraphs of which they indicate the lines upon which they set out to conduct their investigations, and briefly summarise the conclusions which had been arrived at by previous Commissions.

"*Preliminary.*

"1. We have examined a large number of witnesses, and visited various sewage works of many kinds. We have also instituted through our own officers a number of necessary scientific investigations.

"2. Many of these investigations are still in progress, and considerable time must necessarily be taken by the work which still remains to be done, and especially by such work as is needed before the second part of the terms of reference can be adequately dealt with.

"*Questions Considered.*

"3. We have, however, arrived at conclusions on threo questions which appear, for reasons hereafter given, to be of urgent importance, and we have therefore deemed it

INTERIM REPORT, 1901—*continued.*

desirable to make a preliminary report, and to publish the evidence already taken.

"The three questions are:—

(1) Are some sorts of land unsuitable for the purification of sewage?

(2) Is it practicable uniformly to produce by artificial processes alone an effluent which shall not putrefy, and so create a nuisance in the stream into which it is discharged?

(3) What means should be adopted for securing the better protection of our rivers?

"4. Mr. Alfred Douglas Adrian, C.B., who, as Assistant Secretary to the Local Government Board, had charge for some years of the department concerned with questions of sewerage and sewage disposal, was the first witness whom we examined. His evidence contains a most valuable historical statement of the subject of sewage disposal, of the law on the subject, and of the practice of the Local Government Board in regard to this matter. [*Adrian, 35.]

"*Conclusions of former Commissions.*

"5. The first Sewage Commission was appointed in the year 1857. In 1865, as a result of labours extending over eight years, they reported that:—

"'The right way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided.' [52.]

"6. In 1868 a further Commission was appointed to inquire into the best means of preventing the pollution of rivers. They made several reports, the fifth and last being made in 1874. [56.]

"The opinion of this Commission on the comparative merits of the three classes of processes for the treatment of sewage,

* For full names and qualifications of witnesses, see Index to Witnesses (p. 337). The numbers which follow the names are those prefixed to the questions in the volumes of evidence.

INTERIM REPORT, 1901—*continued.*

viz., chemical precipitation, intermittent filtration, and broad irrigation, may be stated thus:—'(1) All these processes are, to a great extent, successful in removing polluting organic matter in suspension. But intermittent filtration is best, broad irrigation ranks next, and the chemical precipitation processes are less efficient. (2) But for removing organic matters in solution the processes of downward intermittent filtration and broad irrigation are greatly superior to upward filtration and chemical processes.' [61.]

"7. The last Commission was appointed in 1882. They were directed to inquire into and report upon the system under which sewage was discharged into the Thames by the Metropolitan Board of Works; whether any evil effects resulted therefrom; and, if so, what measures could be applied for remedying or preventing the same. [71.]

"In November, 1884, they issued their final report. They found that evils did exist 'imperatively demanding a prompt remedy,' and that by chemical precipitation a certain part of the organic matter of the sewage would be removed. They reported, however, 'that the liquid so separated would not be sufficiently free from noxious matters to allow of its being discharged at the present outfalls as a permanent measure. It would require further purification; and this, according to the present state of knowledge, can only be done effectually by its application to land.' [77.]

"*Practice of Local Government Board.*

"8. Since the publication of the last-mentioned report, it has been the practice of the Local Government Board to require, save in exceptional cases, that 'any scheme of sewage disposal, for which money is to be borrowed with their sanction, should provide for the application of the sewage or effluent to an adequate area of suitable land before its discharge into a stream.' There can be no doubt,

INTERIM REPORT, 1901—*continued.*

in our opinion, that the Local Government Board were bound, under the circumstances, to insist upon such a rule. [107.]

"*Reasons for re-considering Position.*

"9. It is now contended that in many cases, especially in the great centres of manufacturing industry, the land available is either of unsuitable quality, is available in quite inadequate area for effective filtration through the soil, or is obtainable only at a prohibitive cost, and it is suggested that sewage purification may, in such cases, be carried out on comparatively small areas artificially prepared. During recent years a variety of artificial processes, differing from those which were considered by the earlier Commissions, have been elaborated for treating sewage, and it is urged that satisfactory effluents can be obtained by such artificial processes. [Tatton, 261, 284, 402-4, 6632; Naylor, 931; Barwise, 4028; Maclean Wilson, 6138-9.]

"*Scope of Work of this Commission.*

"10. Having regard to the definite findings of previous Commissions, to the consequent practice of the Local Government Board in insisting on the provision of land for the purification of sewage, and to the fact that the artificial processes are still only in the experimental stage, and, as might be expected therefore, the evidence in regard to them is inconclusive on many points, it has appeared to us essential to subject the artificial processes to sustained examination, and also carefully to test the contention that in certain cases it is not practicable to purify sewage by land treatment.

"11. At the time of the investigations of the earlier Commissions the science of bacteriology was in its infancy, and these Commissions confined themselves almost entirely to a chemical examination of sewage effluents. Since the dates of those Commissions a large amount of exact know-

INTERIM REPORT, 1901—*continued.*

ledgo has been gained concerning the part played by bacteria in various processes of nature and operations of man, and it became our duty to study the various questions connected with sewage disposal, not only from a chemical, but from a bacteriological point of view as well. This has largely increased our labours, but we trust will also largely increase their usefulness. We have had to initiate and carry out various bacteriological investigations, and, in particular, finding that the work done by earlier Commissions in regard to land treatment was not enough for our purposes, we have thought it necessary to include in our work a systematic investigation, bacteriological as well as chemical, of the treatment of sewage on land of various kinds. This investigation is on the point of completion." [*Interim Report.*]

GRAVITY OF SITUATION.

The gravity of the situation which led to the appointment of the present Commission is clearly shown by the following extract from paragraph 60 of their third report:—

"At an early stage of our investigations we were struck by the fact that in many parts of England the pollution of rivers goes on unchecked, notwithstanding the fact that the Rivers Pollution Act has been on the statute book for over a quarter of a century, and in our interim report we deemed it necessary to state that the protection of our rivers is a matter of such grave importance as to demand the creation of a Supreme Rivers Authority." [Third Report, pp. xxvi, xxvii.]

The deplorable state of affairs above referred to must not be taken as indicating either apathy or neglect on the part of local authorities. The majority of these bodies, in tho larger towns at all events, were keenly alive to the necessity for purifying their sewage. Many of them had already spent large sums of money on sewage works, and others would undoubtedly have followed their example if they could have seen their way to do

GRAVITY OF SITUATION—*continued.*

so with a reasonable prospect of success. The experience of those towns which have taken the lead in this matter has, as a rule, been singularly unfortunate; and a local authority embarking on a system of sewage disposal had before it an endless vista of increasing and, too often, fruitless expenditure.

In this connection the fact should not be lost sight of that the purification of sewage is only one of a large and increasing number of duties with which municipalities are charged, and that the expenditure which some of them have been forced to incur in their attempts to satisfy the requirements of the law in this behalf has made so large a draft on their resources as seriously to cripple them in the discharge of their other responsibilities. It is therefore not surprising that many public bodies should have withdrawn their money and energy for a time from a field in which so little success attended their employment, and applied them in other directions where they could be expended with a fair certainty of success.

ATTITUDE OF LOCAL GOVERNMENT BOARD.

Not the least of the difficulties by which the disposal of sewage was beset was that disclosed by the then President of the Local Government Board, in his reply to a question asked in the House of Commons by Mr. (now Sir William) Mather, M.P., in August, 1893:—

> "It is the invariable practice of the Local Government Board to decline to sanction a loan for any scheme of sewerage or sewage disposal unless it provides that the sewage shall be purified by being passed through land before being discharged into a river or stream to which the Rivers Pollution Prevention Acts apply. They consider that the requirements of those Acts would be contravened unless the sewage is so purified.
>
> "The Board are fully aware that by means of chemical and mechanical treatment very much may now be done to

aid in the purification of sewage, and they therefore approve of a very much less area of land being provided when the authority propose to adopt such treatment; but they are now of opinion that these means alone, without the passing of the sewage through land, are insufficient. Delay has in some cases been occasioned where sanctions to loans have been withheld pending arrangements being made for the acquisition of land."

Deadlock through insistence on Land.

A notable instance of the deadlock brought about by the insistence of the Local Government Board on land treatment occurred three years later, in connection with an application by the Corporation of the county borough of Salford for permission to borrow £50,000 for the purpose of carrying out a scheme of sewage disposal, prepared by the borough engineer, and adopted by the Council on 30th December, 1895.

The scheme comprised some slight alterations of the existing precipitation tanks, the conversion of two of them into roughing filters, and the construction of about 24,000 squaro yards of aërating or bacterial filters, with special pipes, valves, effluent culvert, &c., together with buildings and plant for the preparation, cleansing, and renewal of the filtering material.

A local inquiry was duly held, and on 1st September, 1896, one of the Assistant Secretaries to the Board wrote to the Council as follows:—

> " The Board direct me to state that they cannot accept the proposed scheme as a sufficient one, and that, before they will be in a position to sanction a loan, it will be necessary for the town council to acquire an adequate area of land over which the effluent should be passed after the sewage has been treated chemically, as proposed by the town council."

No objection was raised by the Board to the general principle of tho scheme submitted, with respect to which tho Corporation

Deadlock through insistence on Land—*continued.*

pointed out that it "had for years past conducted practical experi-"ments with almost every known system of sewage treatment, "and acting on the experience thus gained, and on the scientific "reports on the results of these experiments, had adopted the "scheme proposed as the best artificial treatment of sewage "practicable, under existing conditions, which fulfils without "excessive cost the requirements of the" (Mersey and Irwell) "Joint Committee." [Report of the Rivers Conservancy Committee to the Council of the County Borough of Salford.]

The Corporation goes on to express the opinion that the application of the effluent to land is, "in view of the excellent experimental results obtained, unnecessary," and points out that such application would involve a capital expenditure, in addition to the £50,000 already applied for, of £87,000, and maintenance charges of nearly £7,000 per annum. The Board was, however, inflexible, and at the end of a fruitless correspondence extending over ten months, the Council decided to withdraw its application and raise the money required for the works by other means not requiring the sanction of the Local Government Board.

The feeling as to the obstructive nature of the insistence on land was not confined to local authorities charged with the purification of sewage, but extended also to those whose duty it was to enforce the law prohibiting the pollution of rivers.

Thus, as early as October, 1893,

> "It was proposed that a deputation from the" (Mersey and Irwell) "Joint Committee should wait upon the Local Government Board to urge that considerable delay was taking place in the progress being made by local authorities with their sewage schemes owing to the Board's requirements as to the purchase of land." [Tatton, 259.]

And at a meeting held on 5th July, 1897, the Committee, after considering reports by their scientific adviser, Sir Henry Roscoe, F.R.S., D.C.L., LL.D., and their chief inspector, Mr. R. A. Tatton, M.Inst.C.E., resolved that—

Deadlock through insistence on Land—*continued.*

"A deputation from this Joint Committee wait upon the Local Government Board with the view of showing the objections to a hard and fast rule being laid down with regard to land filtration."

The difficulty of obtaining land was also referred to by Dr. H. Maclean Wilson, M.D., B.Sc., Chief Inspector of the West Riding of Yorkshire Rivers Board, who mentioned the case of Todmorden as one in which

"A schome for their sewage disposal has been delayed for a very long time because the sanitary authority have not been able to meet the requirements of the Local Government Board." [Dr. Wilson, 1029.]

Similar testimony was given by two of the county medical officers who were examined by the Commissioners:—

"The greatest difficulty we have had in Derbyshire in getting things carried out is on account of the Local Government Board's land requirements." [Barwiso, 4040.]

"As the result of personal observations and experience, I have arrived at these conclusions:—

"5. That, in this county (Glamorgan) at any rate, greater progress would have been made in purifying our rivers had not the Local Government Board insisted, under all circumstances, on the hard and fast rule of land treatment, in addition to artificial filtration. At the moment, progress on this account is at a standstill in several districts." [Williams, 9819.]

Tho Local Government Board have bcen blamed in many quarters for their rigid insistence on land treatment. It is therefore noteworthy that the Royal Commission in the eighth paragraph of its Interim Report, already quoted, expresses the opinion that the Board "were bound under the circumstances to insist upon such a rule." The reconsidoration of the rule in question virtually constitutes the main part of the task assigned to the present Royal Commission.

CHAPTER II.

THE PURIFICATION OF SEWAGE ON LAND.

Definitions.

There are two methods in which land is employed for the purification of sewage, known respectively as "intermittent filtration" and "broad irrigation." Definitions of these were obtained from several of the witnesses, among others from Dr. H. Maclean Wilson, who said:—

Intermittent Filtration.

"I think there are, Sir, certain cases that you could show were definitely cases of intermittent filtration; for instance, where the land is laid out in plots with banks all round, and the sewage is run upon these plots, and after a charge has been put upon the plot the sewage is allowed to stand until it filters away: that is definitely intermittent filtration. [Dr. Wilson, 6180.]

Broad Irrigation.

"On the other hand, you have some instances which are certainly broad irrigation, where, as at Harrogate the Commission saw, the sewage is allowed to run over the surface of the land and gradually lose itself by percolation and evaporation. That is broad irrigation; but there are all sorts of intermediate kinds of treatment between those two." [6181.]

"(Chairman): Well, now would you mind defining what you call broad irrigation?—I should define it roughly that if land is used for broad irrigation you have no drains; it is not drained at all. If it is used for intermittent filtration it is drained. The line is rather an ill-defined one between the two systems, but that is, generally speaking, the accepted definition." [Tatton, 6581.]

DEFINITIONS—*continued.*

Other witnesses also laid stress on the absence of any radical difference between intermittent filtration and broad irrigation :—

> "How would you distinguish between broad irrigation and intermittent filtration?—I say the line of demarcation depends upon the nature of the soil; you cannot help a sewage getting through a very porous soil, and in that way the line of demarcation between broad irrigation and filtration is not very distinct." [Chatterton, 6427.]

The principle of broad irrigation and its capabilities were dealt with by Mr. Strachan.

> "In flowing sewage along the surface, will you explain what the method of procedure is, assuming the land is level. Do you mean that you flood the land?—No, I would let it run on, with a very slight gradient at the top, in as thin a film as possible, and let it flow continuously over it. [Strachan, 7738.]
>
> "And the land is not underdrained?—No. [7739.]
>
> "The sewage is not encouraged to pass through the land? —No. [7740.]
>
> "Some of it will pass through it?—Undoubtedly. [7741.]
>
> "A part of it will pass over it?—Will pass over it." [7742.]
>
> "But you have experience of flowing sewage over a surface in that way?—Oh, yes. [7744.]
>
> "And do you obtain much purification in that way?—Oh, yes." [7745.]

Cf. 7508 *et seq.*, 8109*, 10094.

The Officers of the Commission, in their General Report on Land Treatment, take exception to the terms, "intermittent downward filtration" and "broad irrigation," and propose in their stead "land filtration" and "surface irrigation." [*Fourth Report*, vol. IV. pt. I. p. 106.]

* An asterisk following a number is used in the Reports to denote the second of two answers bearing the same number.

Sewage Farms in their Relation to Health.

Irrigation originally in Disfavour.

In view of the present leaning of the Local Government Board towards the treatment of sewage by means of land, it is interesting to recall the fact that not so very long ago land treatment was regarded with considerable suspicion. That veteran sanitary reformer, Mr. (afterwards Sir Edwin) Chadwick (now deceased), in his evidence before the Commission appointed in 1843, expressed an opinion "by no means favourable" to irrigation. [Adrian, 9.]

The General Board of Health, also, in their Report presented on 6th January, 1854, appear to have damned the practice with faint praise. [25.]

So recently as 1869, the late Dr. Alfred Carpenter, in the "Introduction" to his paper entitled "Some Points in the Physiological and Medical Aspect of Sewage Irrigation," read at the Social Science Congress at Bristol, entered a vigorous protest against the unfair treatment which was experienced by those who advocated the utilisation of sewage on land. The tactics which he describes are so strangely like those which have been resorted to of late years by the opponents of bacterial treatment that a few extracts from his "Introduction" may appropriately be quoted here:—

> "The attention that sewage irrigation is now receiving in all parts of the United Kingdom, as well as in almost all civilized parts of the world, is a fair proof of the success which has attended the establishment of sewage farms in those few places which were bold enough to make the experiment. It must be conceded that the evils which were prophesied as not only likely but certain to arise have not yet made their appearance, and the general public is beginning to understand something of the matter, and to discredit the prophets of evil. It seems, however, that the nearer we approach to success, the more violent the enemies of the system become. This is really nothing more than might be expected, though it should be understood that the promoters of sewage irrigation have never asserted that it is

IRRIGATION ORIGINALLY IN DISFAVOUR—*continued.*

the only plan which ought to be adopted for the disposal of sewage matter, but that, 'when carried out in a scientific manner, it removes the difficulty which arises from the noxious plan of polluting the rivers of England, and that there are circumstances in which other systems may be applicable' (*vide* 'Proceedings of Sewage Congress at Leamington, 1866,' p. 248). The supporters also say it is free from danger, when used in a scientific manner. It does not, therefore, seem quite just that the promoters of other plans for the utilization of sewage should be amongst its most ardent and unscrupulous opponents, that they should be the disseminators of reports calculated to raise the fears of the rate-paying and health-seeking public. Wherever it is proposed to establish a sewage farm, they try to prevent the plan from being adopted by most unfair means. When we consider the matter, it seems, however, that sewage irrigation has to bear up against onslaughts in a manner similar to that which every other truth has had to submit to. . . .

"The opponents of sewage irrigation let their imagination have full play, and depict all manner of evils as likely to arise. They assert the most extraordinary tales regarding the result of sewage application in those places at which it has been tried, and urge upon those having the power tho positive duty of staying the suicidal action of the promoters of irrigation. Publications are thrown broadcast over the town, the local press teems with the statements made by some unknown 'A. B. C.' showing the frightful state to which certain towns have been reduced in consequence of the adoption of sewage farming."

The attacks which Dr. Carpenter deprecates above were powerless to prevent the introduction of sewage farms; and these have now been used so widely, on so large a scale, and for so many years, as to give full opportunities for testing their influence upon health. There seems to be a consensus of opinion that a properly-managed sewage farm at a reasonable distance from habitations is not, under ordinary circumstances, dangerous to health. See also pp. 307, 308.

One of the "chief conclusions" of the preliminary report made by the first Sewage Commission in 1858, quoted by Mr. Adrian in his evidence, was as follows :—

"That the application of tho whole sewage to land, while

IRRIGATION ORIGINALLY IN DISFAVOUR—*continued.*

profitable in certain cases, was not, when conducted with moderate care, productive of nuisance or injury to health." [Adrian, 37.]

The same question is dealt with by other witnesses.

"You do not consider there is any injury to health from the fact that there is so much of the land in the neighbourhood absorbing sewage?—I should not like to say that, definitely; there are many of the sewage works in the Riding, I think, far too close to populous neighbourhoods, and although I could not point to any definite injury to health, I would be strongly of opinion that having mismanaged sewage farms near populous neighbourhoods was injurious. [Dr. Wilson, 1019.]

"You would?—Yes; not that it produces any definite disease, but a general deterioration of health." [1020.]

"Have you ever known any injury to health to come from the sewage farms?—Never, I think." [6273.]

"But you have had experience of land treatment of sewage?—Yes. [Mawbey, 8092.]

"And you would say positively, in your opinion, it produces no injury to the health either of human beings or stock?—I think not." [8093.]

It is doubtful, however, whether sufficient regard is paid to that phase of irrigation which is dealt with by the General Board of Health in the Appendix to their report presented in 1848:—

"Can you tell us what, briefly, is the effect of those conclusions of the General Board of Health?—The General Board of Health were of opinion 'That the application of manures to the surface of land by means of irrigation is less injurious than the application of the same quantities of manure in the common method as top-dressing, but that the common practice of irrigation with plain water is often productive of ague, and, when conducted near dwellings, is otherwise injurious to health; and that the creation of largely-extended evaporating surfaces from sewer water near towns (though still far less injurious than the retention of refuse and its decomposition within towns and underneath habitations) ought to be avoided.'" [Adrian, 25.] See also p. 307.

Efficiency of Land Treatment.

The rise of land treatment in the estimation of competent judges is testified to by the extracts from previous reports quoted by the present Commissioners, and reproduced in the Introductory Chapter.

Its efficiency under suitable conditions is conceded, with hardly an exception, by every witness who was questioned on the subject. Quotations to this effect might be multiplied indefinitely, but it will suffice here to give extracts from a few of the answers in which the advantages of land treatment are set forth :—

> "Soils, however, and the roots of growing plants, have a great and rapid power of abstracting impurities from sewage water and rendering it again innocuous and free from contamination . . . .
>
> "If the sewage of towns is no longer to flow into rivers, the only alternative which remains is to dispose of it on the land." [Adrian, 49. Report of Select Committee appointed by the House of Commons in 1864 to inquire into any plans for dealing with tho sewage of the Metropolis and other large towns, with a view to its utilisation for agricultural purposes.]
>
> "Irrigation is the only process of cleansing sewage which has stood the test of experience, and unless it be extensively adopted there is but little hope of any substantial improvement in our sewage-polluted rivers." [63. Second Report of the Rivers Pollution Commissioners, 1870.]
>
> "It is, however, necessary not to lose sight of the fact, which would, I think, be supported by high scientific evidence, that *if suitable land is obtainable*, filtration through land is the most permanent and satisfactory method of treatment. This is fully borne out by the experience on the Mersey and Irwell watershed, where the proportion of works with land treatment giving satisfactory results is considerably higher than those with artificial filtration." [Tatton, 259.]
>
> "With regard to the methods of treatment, I would point out that the reports, which Mr. Tatton and others have presented, show that *where suitable land can be obtained, which, in the part of England referred to, is only to be done in*

Efficiency of Land Treatment—*continued.*

isolated cases, no doubt the best results can be thereby gained from a purification point of view." [W. H. Wilson, 769*.]

"As a rule, broad irrigation is fairly successful in the West Riding, because it has usually been adopted in quite rural districts, where the refuse is purely domestic. In the places where it has failed it has been due chiefly to the nature of the land." [Dr. Wilson, 1342.]

"(Major-Gen. Carey): If sewage can be applied to a sufficient area of suitable land, do you consider that that is the best and most satisfactory means of dealing with it?—Yes." [Crimp, 1761.]

"The two main methods in use are, first, land filtration, including broad filtration (sewage farms); and in the second place, artificial filtration. With regard to the first method there is no doubt that, *where the conditions are suitable, and where the process is efficiently carried out*, the results are satisfactory. I may say that on the Mersey and Irwell watershed we have evidence of this." [Roscoe, 3511.]

"*If the land can be obtained in quantity sufficient, if it is suitable, because it must be suitable as well as in area sufficient; and if the rainfall in the neighbourhood is not very serious*, I think such filtration is very excellent." [3711.]

"The best effluents I have submitted to me for analysis are after treatment by land, and these carry the largest amount of suspended matter." [Scudder, 5972.]

"I look upon land treatment as quite out and out the best thing to do with inland sewage, *if you can have plenty of land.*" [Strachan, 7626.]

"We presented a report on the effluents from the sewage farms in England to the Local Government Board, showing that land filtration did give you a standard effluent." [Scudder, 6080.]

"If the soil is perfect, and the management good, it does; but if the soil is not good and the management not good, it will not do?—On clay soil, of course, you cannot do it; you want suitable filtering soil." [6081.]

"The treatment of sewage on suitable land is satisfactory, *provided the areas are properly supervised, which is not always found to be the case.*" [Dr. Williams, 9819.]

EFFICIENCY OF LAND TREATMENT—*continued.*

Since the publication, in 1884, of the report of the Metropolitan Sewage Commission,

> "The" (Local Government) "Board have regarded themselves as justified, save in exceptional cases, in requiring that any scheme of sewage disposal for which money is to be borrowed with their sanction should provide for the application of the sewage or effluent to an adequate area of suitable land before its discharge into a stream." [Adrian, 107.]

It may be noted here that land treatment is not insisted on by the Local Government Board for Scotland. [Murray, 208, 210.] The practice of the Irish Board, however, is modelled on that of the Department for England. [Deane, 243.]

RELATION OF AREA TO FLOW.

There is no question in connection with the purification of sewage which needs more careful consideration than that of the area of land which is required to deal with a given volume of sewage.

A correct judgment on this point can only be arrived at by the aid of wide and prolonged experience, with full regard to the nature of the sewage and the physical and other characteristics of the land. The statistics collected by the Commissioners of the quantity of sewage per acre dealt with on different farms, together with the opinions which they have elicited from a large number of witnesses able to speak with authority on the subject, constitute one of the most valuable features of their reports, and in view of the importance of the subject some space may well be devoted thereto.

> "At Edinburgh, where sewage irrigation is followed, it is not worked for the purpose of purification, but for the purposes of utilisation. There they only filtered two gallons per square yard per day. Perth, that is only ·4 of a gallon per square yard per day. And Warwick was one and a quarter gallons with clay land, and was a failure. Take good soil; for instance, at Croydon they are able to filter four gallons per square yard, while clay soil was only ·8. *If you are going to take large towns, and it is those we want to deal with, the area of land required is outrageous; it is not practicable to apply the sewage of a large town to irrigation over land.*" [Scudder, 609.]

Relation of Area to Flow—*continued.*

"(Major-General Carey)—I suppose it may be combined with precipitation, may it not?—Quite so. Take, for instance, the population of Manchester. They have already adopted precipitation; they have tank accommodation for the whole of the sewage; they precipitate the whole of it; they get an effluent which is not fit to be discharged into any river; they must carry out some form of filtration. If it is land filtration, from the experiments we have made at Manchester, they cannot filter more than 60,000 gallons; it would not be advisable to attempt more than 60,000 per acre, and consequently they would want nearly 1,000 acres of land." [610.]

"When you come to estimate what area of clay land will be necessary, it is ridiculous to ask them to acquire that area of land; they cannot get that area of land." [675.]

"This very first-class soil would purify effectually sewage effluent, after it had been clarified, at the rate of 30,000 gallons per acre per day, constantly, without becoming sewage sick; but that was its limit." [Crimp, 1571.]

"On clay soils the number of gallons per acre that you can purify depends entirely upon the depth of top soil. There is on every field a certain depth of top soil which is porous, and therefore contains vast numbers of the organisms which we know now are the agents which purify the sewage, and there is a rough sort of proportion which can be formed as to the amount of sewage which can be purified on clay soils by ascertaining the depth of the friable porous top portion. If, for example, the depth is six inches, it will purify about one-sixth of the 30,000 gallons that I have already given you, that being one-sixth of three feet; and I put it in that way because we know now that nearly all the purification that is done, even on porous soil, is done on the top three feet." [1578.]

"For permanent pasture, I think about 3,000 gallons per acre; 3,000 to 4,000 gallons per acre would be about the limit there, depending on the amount of surface soil you find there to begin with." [1583.]

"The result of the Merthyr Tydvil purifying filters was that the sewage of 3,000 people could be efficiently treated upon an acre of land—of suitable land—provided it were drained six feet deep." [Sir E. Frankland, 3070.]

Relation of Area to Flow—*continued.*

"At Swadlincote, the sewage from a population of 12,000 drains on to an area of sixty acres, giving 200 persons per acre. The geological formation is Bunter sandstone and drift, and we get a good effluent." [Barwise, 4022.]

"Would you expect a satisfactory effluent to be produced from a small area of clay land with the high rate, say, of 1,000 population to the acre after chemical treatment and precipitation?—Certainly not. I do not think that more than 300 per acre is as much as ever ought to be put on." [Latham, 4667; see 4670.]

"You do not know what the proportion of population per acre is to the Beddington Farm; 600 acres are under cultivation?—I suppose there would be about 90,000 people draining into that outfall at the present time." [4676.]

"(Colonel Harding): You use each acre in turn; you turn the whole of your daily flow on to each acre, such daily flow being 350,000 gallons?—That is so." [Edson, 5333.]

"At the end of the twenty-four hours you give that bed eleven days' rest, during which time the sewage passes on right through." [5334.]

"(Colonel Harding): Then do you think the time is coming when one day in twelve will be too much to give them?—Yes, I think so." [5357.]

"You have a table to hand in to the Commission?—I have, it is as follows:—

[Table—Approximate Areas.

RELATION OF AREA TO FLOW—*continued.*

APPROXIMATE AREAS REQUIRED UNDER VARYING CONDITIONS. (ARABLE LAND.)

		Direct to Land. 2 (a).		After Precipitation or Mechanical Settlement. 5 (a), I. and II.		After Filtration on Bacteria Beds. 5 (a), III. and IV.	
		Ratio of Population per Acre.	Acres per 1,000 Persons.	Ratio of Population per Acre.	Acres per 1,000 Persons.	Ratio of Population per Acre.	Acres per 1,000 Persons.
Broad Irrigation.	Gravel	100	10	500	2	1,000	1
	Light Loam...	100	10	500	2	750	1⅓
	Heavy Loam..	75	13⅓	200	5	400	2½
	Chalk............	...	...	...	...	...	...
	Peat	Unsuitable.		Unsuitable.		Unsuitable.	
	Clay	50	20	100	10	300	3⅓
		2 (b).		5 (b), I. and II.		5 (b), III. and IV.	
Intermittent Filtration.	Gravel	150	6⅔	500	2	1,000	1
	Light Loam...	150	6⅔	500	2	1,000	1
	Heavy Loam..	75	13⅓	300	3⅓	500	2
	Chalk............	...	...	...	...	...	...
	Peat	75	13⅓	200	5	400	2½
	Clay	Unsuitable.		Unsuitable.		Unsuitable.	

[Tatton, 6578.]

"What area of each kind of land is required for 1,000 persons, assuming a dry-weather flow of 30,000 gallons per day: (a) for broad irrigation; (b) for intermittent filtration when the sewage is first (1) allowed to settle mechanically, the solids not going on the land; (2) chemically precipitated and then allowed to settle, the solids not going on the land; (3) chemically precipitated and then filtered; (4) subjected to treatment in bacteria beds?—If the solids are prevented

Relation of Area to Flow—*continued.*

from going on to the land there is probably little difference, from the point of view of its effect upon the land, between mechanical settlement and chemical precipitation, provided that the chemicals used do not retard biological action; but as the solids will not settle as rapidly without chemicals as with them, tanks used for mechanical settlement should have a larger capacity; we may therefore class 1 and 2 alike. (1 and 2) If the land is of good quality it should deal with a population of 500 per acre after the solids are removed, either by broad irrigation or by intermittent filtration. This is the ratio at Wilmslow (northern outfall), population 2,500, and at other small places on the Mersey and Irwell watershed. At Eccles, population 35,000, where the land is heavy loam, somewhat lightened by ashpit refuse and underdrained, the ratio is also 500 per acre, the sewage being previously mechanically settled. The results are satisfactory; but owing to the rapidity with which storm water reaches the works a dilution of 6 to 1, at which the storm overflow is fixed, is soon reached, and much storm water goes away untreated. (3 and 4) The answer to this question depends upon the efficiency of the precipitation and filtration processes. If they are efficient and the effluent from the filters or bacteria beds is of such a character that the organic matter left in it is insufficient to cause it to putrefy, there will be little left for the land to do, and the factor of how much water the land will pass will be the important one, giving due regard to intervals of rest. If, on the other hand, the purification effected by the filters or beds is only partial, the remainder of the work will have to be done by the land, and the area required will be in proportion to what has to be done." [6585.]

"Could you briefly tell us how you formed these opinions? —On the Mersey and Irwell watershed the Stretford farm is one of the most satisfactory ones, and the effluents obtained from it are invariably good; the sub-soil is alluvial; the farm is drained throughout. In 1895, the population (8,500) draining to it was at the ratio of 200 persons per acre, but the land was found to be getting overworked, and an extra area has been bought which has reduced the area to 150 per acre. The farm is arable, and deals with the whole of the storm water except in exceptional storms. A good

Relation of Area to Flow—*continued.*

example of the broad irrigation system is the Croydon sewage farm at Beddington, where the storm water and sewage from a population of 100.000 persons is dealt with on an area of 450 acres, giving a ratio of 222 to the acre. The farm, however, is worked to its utmost capacity, and the engineer is now putting down contact beds with the object of reducing the amount of sludge which tends to foul the land: it is very suitable as regards position and fall, has a gravelly sub-soil, and is very well laid out. It is evident, therefore, that even under the most favourable circumstances, a ratio of 222 persons to the acre is too high for a broad irrigation farm; 100 is probably a safe limit to commence with, which might be raised in exceptional cases to 150. . . . At Tyldesley (population 14,500) and West Houghton (population 10,500), clay farms were in operation in 1895, the ratio of persons to the acre being, in the case of Tyldesley, 100, and West Houghton, 175. The treatment in both cases was a complete failure, and precipitation tanks and filter beds had to be constructed."

"As to the amount of sewage which can be treated on a clay broad irrigation farm, I should say that the ratio should not be greater than 50 persons per acre; it is possible that this estimate is a too hopeful one; the whole of the treatment will have to take place on the surface, and longer periods of rest will have to be allowed for the land to dry, as this will be effected more by evaporation than by percolation." [6632.]

"What would you say was the greatest amount of gallons that an acre of best land would deal with?—I cannot tell you what it would take; I will tell you what I put on it myself. I do not know what the limit might be. I would not put upon what I call stiff, harsh lands more than 3,000 gallons to the acre, and upon the very best lands that we have got I know nothing which would justify me in putting on more than 30,000; but land may be capable of dealing with more. I merely know of no experience which would justify me in doing it." [Strachan, 7625.]

"I may say for years that I have been looking out for the place that is dealing with 2,000 persons to an acre. I have visited, I think, all the places that I have heard of,

Relation of Area to Flow—*continued.*

and it does not exist that I can find, and I have come to the conclusion that it never did exist." [7631.]

"In another part of your evidence, where you were talking about land treatment, you said that if an effluent from artificial filters is passed finally over land, that you think it likely that a larger quantity than 30,000 gallons per acre could be dealt with, provided it is not made to go through the land, but allowed to go along the surface?—Yes, I gave expression to that opinion." [7737.]

"What I want to guard myself against is, that 30,000 gallons per acre represents the maximum that the best land will do." [7743.]

"I would instance the small town of Desborough, not very far from Kettering, in Northamptonshire, which farm I went to inspect in my professional capacity. I found there a farm of four acres in extent, dealing with a population of 3,000 people, and dealing with it in a most satisfactory way. There was no precipitation, the only thing that was done was to strain the sewage as it was delivered on the farm from floating matter, to pass it into one tank, which might be called a settling tank, from which the deposit was at times removed. After a short subsidence there, the sewage was poured down over the land, and, as I say, was most efficiently dealt with. The whole secret there was, that you had a beautiful piece of land for the purpose. There was a nice rich sandy loam, fully four feet in depth, rich Northamptonshire land. . . . . I hope it will not be taken, of course, that I am advocating that anything like 3,000 people can be dealt with on four acres of land. I simply give that as an instance of what can be done where land is suitable, and where the farm is, as was the case here, managed by a competent man who knew his business." [Voelcker, 10164.]

"I will put it to you in this way. On each acre of land which we have available for the purpose of irrigation, whether by broad irrigation or downward intermittent filtration, we are putting sewago from a population of 460 persons. [Watson, 14585.]

"What does that come to in gallons?—In gallons that would be about 15,000 gallons an acre. [14586.]

"Then you find it practicable to deal with septic tank

RELATION OF AREA TO FLOW—*continued.*

effluent on your kind of land to the extent of 15,000 gallons per acre ?—I do. [14587.]

"But you think it inadvisable to go beyond that ?—I think I am going too far now. [14588.]

"From your experience, how far do you think it is safe to go ?—Not more than 300 people to the acre. [14589.]

"That would be 12,000 gallons ?—Rather less, 10,000 gallons per acre." [14590.]

"What is the nature of your land, is it open gravel ?—It is very varied. We have all kinds of land, really. We have close, stiff clay, we have marl, we have gravelly material, we have gravel, we have a very little sand, and I am sorry to say we have a good bit of peat." [14592.]

"Is the land at your disposal sufficient for the purpose now, and likely to be sufficient for some time to come ?—It is not. *Our increase of population is so great that we would require to buy and to lay out more than an acre per week to keep pace with the increase.*" [14579.] See 1512 *et seq.*, 3073, 3741 (60,000 g. d.), 4505 (300 people per acre), 4515, 6136, 13035.

The capacity of land for receiving and dealing with sewage is sensibly limited by the rainfall upon its surface, which sometimes, over a given area, equals in an hour or two the volume of sewage which most competent judges regard as the utmost which can be safely put upon it in a day; and, unfortunately, the saturation of the soil with its own rainwater occurs just at the time when the quantity of sewage with which it is called upon to deal is greatest. The extent to which land is affected by this cause, will, of course, depend in great measure upon its porosity. As pointed out by Sir Henry Roscoe, "the rainfall is a point upon which I think much stress has to be laid." [Roscoe, 3713.]

It can hardly be said that it has received the attention which it deserves.

It will be noticed that in the foregoing quotations a distinction is drawn between raw sewage and that which has undergone a preliminary treatment for the removal of the solid matter. This distinction has been recognized by the Local Government Board in the rules which, "after much consideration, were adopted in 1890," and which were quoted by Mr. Adrian as follows :—

"For treatment by broad irrigation only: Land in the proportion of not less than one acre to every 300 of the population must be provided. For treatment by intermittent

Relation of Area to Flow—*continued.*

downward filtration only: There must be not less than one acre to every 1,000 persons. For broad irrigation in combination with chemical treatment: There must be not less than one acre to every 1,000 persons. For intermittent downward filtration in combination with chemical treatment: There must be not less than one acre for every 2,000 persons. It should, however, be stated with regard to these rules, that their application is subject to special consideration of the actual circumstances of each case. The Board do not look upon themselves as tied to a uniform and strict observance of the scale. Cost, character of land, and probable increase or decrease of population, among other circumstances, have to be recognized as grounds of exception." [Adrian, 108.]

Some seven years ago, about the time of the introduction of biological methods of purification, the Board reduced by one half the amount of sewage which, after preliminary treatment, might be disposed of on an acre of land, and where land is used they are now accustomed to call for at least one acre per thousand of population. See also pp. 305, 313, 315 *et seq.*

Kinds of Soil best suited for Irrigation.

"The best class of soil that I have found anywhere for purifying sewage is the alluvium found in most river valleys —not in all, of course. There are many square miles of beds of these river gravels in the Thames valley which, when above flood level, are extremely well adapted for the purpose. The best soil I know usually consists of about fifteen inches of good porous top soil, and under that a bed of gravel. That I consider the very best soil." [Crimp, 1570, 1571.]

"There is considerable difference in the qualities of lands which are suitable for the purposes of direct application of sewage. Porous, gravelly subsoil, with a fairly retentive soil on the surface, is, without doubt, the most effectual for disposing of large quantities of sewage. On the other hand, clay soils are those least adapted to the purification of sewage." [Latham, 4505.]

"(Major-General Carey): Then, I suppose, in gravelly soil, which is the second class which is unsuitable as being too porous, the result is to a great extent mechanical; there is no time for bacterial action to take place?—That depends

KINDS OF SOIL BEST SUITED FOR IRRIGATION—*continued.*

very much upon tho drainage. If the drainage is very rapid the filtration will be mechanical, but if there is no underdraining then you get a slower action and bacterial effect." [Dr. Wilson, 6171.]

"Light or medium soils resting on a sandy subsoil will be found the best absorbents of sewage, although their power of retaining the fertilizing ingredients is not so great as that of heavy clays. On stiff clay lands, the chief fault of which is their impertransible nature, large dressings of town sewage would not be beneficial, nay, would be the reverse. The fluid would rest on the surface and render the soil so cold and wet as to be decidedly injurious to most plants." [Sir C. A. Cameron, 13035. See also p. 314.]

It may be observed that the land which effects the greatest amount of purification will not, as a rule, be that which is capable of dealing with the largest volume of sewage, the characteristics which make for efficiency in point of quality of the effluent being to some extent opposed to those which confer the power of treating large quantities on a given area.

UNDERDRAINAGE.

While it is customary to speak of land in terms of its superficial extent, the area, taken alone, does not constitute its measure for sewage purification purposes. This point was well put by Mr. Santo Crimp in his answer (No. 1578), already quoted on page 20, relating to clay soils. He stated there that the capacity of land to purify sewage depends on its depth; the volume of soil, rather than its area, being the measure of the quantity which it can deal with. The case to which he referred was that of a porous surface layer resting on an impervious subsoil, but the limitation of the purifying power of land is hardly less effective when it is imposed by a high saturation level in the subsoil.

The function of underdrainage is to lower the saturation level, and so to render a greater volume of aërated ground available for filtration purposes, at the same time promoting the circulation of the subsoil water.

The utility of land drainage in certain cases was insisted on by several of the engineers and other scientific witnesses who were called by the Commissioners.

"I think on porous soils, whether underdrainage is

UNDERDRAINAGE—*continued.*

required or not, would depend entirely upon the line of saturation . . . . . You might lower your subsoil water to the extent of four or five or six feet, and in that case you are doing good work." [Crimp, 1774.]

"I think a gravelly soil may be underdrained, and deal with enormous quantities of sewage." [Latham, 4671.]

"If you have got a sewage of 1,000 people to the acre to put on to the soil, it would be absolutely necessary to drain it. You would not get it through; you would not get it purified; it is simply passing it over at that rate." [4672.]

"I am very much afraid of putting sewage directly over an underdrain; but you must have sufficient underdrains, so as to keep the level of the subsoil water down, and to keep your land always sweet." [Chatterton, 6431.]

"Peat land must be underdrained, because, being so absorbent, unless it is you would never get rid of the water from it; it would be always in a spongy condition." [Tatton, 6635.]

"Now, as to underdrainage of land; you say all land should be underdrained more or less?—Yes." [Balfour, 6880.]

"I think, with a volume such as that put upon the land, it really wants some artificial relief to some extent, more or less." [6882.]

"Do you consider that a sewage farm, as a rule, should be underdrained?—As a rule, I might say, it should be underdrained. But in the case of very heavy clay soils I should not advise it, because of their liability to crack in dry weather, thus allowing the sewage to go through unpurified." [Voelcker, 10215.]

The inadvisability of draining heavy clays, to which Dr. Voelcker calls attention, is laid stress on by other witnesses :—

"Well, if you want to ruin a clay farm, you can do it quite readily by underdraining it, because you cannot by any possibility convert an impervious bed of clay into a pervious bed by putting in underdrains at intervals of half a chain or so apart. What really does happen in such cases is to cause the ground to crack even more so, far more so, in fact, than it would do naturally. The sewage then passes down the cracks into the sub-drains and goes away unpurified; so that, unless you can do as we have done at

UNDERDRAINAGE—*continued.*

> Wimbledon to some small extent, and as has been done more recently at Leicester, unless you can bring those drains out on to the surface of your sewage farm lower down, where you can re-apply the sewage after it has come out of these drains, underdraining is a mistake in clay lands. If clay lands are underdrained it should be done with the greatest of care, and places should be looked at where underdraining has been done, and the result very carefully examined into." [Crimp, 1587.]
>
> "I know, for a fact, that it is a very great mistake to put a single underdrain under very stiff clay." [1760.]
>
> "Clay land . . . . . must not, on any account, be drained, as cracks occur in dry weather, which permit the sewage to find its way unpurified into the drains." [Tatton, 6632.]

Mr. Baldwin Latham also, referring to the Norwood farm of the Croydon Corporation, which was a stiff London clay with a very slight covering of clayey soil, and was originally underdrained, said, "We had to take the whole of the drains out, and it never succeeded until the drains were taken out." [Latham, 4649.]

The disrepute into which underdrainage has fallen in connection with clay soils is undoubtedly due, in great measure, to the way in which the work has sometimes been carried out. Cases are not uncommon in which the trenches have been filled in with ballast or other loose material, thus giving direct access from the surface down to the pipes. It is almost superfluous to point out that work of this kind cannot fairly be described as underdrainage, and that pipes laid in such trenches are little more than covered carriers for surface drainage. Their behaviour in this capacity, therefore, affords no ground for forming an opinion as to the desirability or otherwise of underdrainage proper. One is, however, bound to admit that there are grave drawbacks attached to the underdrainage of stiff clays, unless the land is so situated as to admit of the imperfectly purified effluent from one set of drains being turned over lower ground, as was done at Leicester by Mr. Mawbey. [Mawbey, 8095.] Less would have been heard of failures due to underdrainage if the obvious precaution mentioned by Mr. Chatterton, namely, to avoid putting sewage directly over a drain, had been more generally observed. [Chatterton, 6431.]

Influence of Frost on Sewage Farms.

Little divergence of opinion was manifested as to the effect of frost on the purification of sewage by land.

"Have you any opinion as to how frost and snow would affect purification?—Very hard frost will affect purification on clay land. . . . But in ordinary winters, I think that no trouble is found as regards frost. The temperature of the sewage itself usually keeps either the filter beds or the land open. [Tatton, 6612.]

"You do not think it is a very important question?—No, I do not think it is." [6613.]

"The relative inefficiency of land treatment during frost was already pointed out by the Rivers Pollution Commissioners." [Dr. Frankland, 9927.]

"Yes, so far as we are able to trace it, the effluent is good all the year round. The question did arise as to whether the winter temperatures would be inimical to the action of the purifying agent, but, I think the evidence, so far as I have been able to obtain it, shows that the winter temperature does not interfere materially. [Roscoe, 3512.]

"And when the land is frozen, does it do any harm?—Well, I have not had cases where the land was frozen." [3513.]

"But would it not flow over the surface of the frozen land, instead of flowing through it?—Oh, in case of land filtration there would no doubt be a difficulty." [3515.]

"Do you think that when the land is frozen any purification of sewage takes place?—I have never found any difficulty with regard to it." [Latham, 4512.]

"Then, in fact, you think the purification goes on in very cold weather, and throughout the English winter?—Oh, indeed it does, there is not a shadow of doubt about it." [4514.]

"Speaking generally, the effluents analyse just as well in the winter time as in the summer." [Dr. Wilson, 6255.]

"And do you find that frost or very cold weather affects the purification on land?—I have not experienced that. I daresay if the effluent was analysed, and I am speaking merely as an engineer, it may be that it is not quite so good in the winter as it is in the summer." [Strachan, 7626.]

From a perusal of the foregoing we may safely conclude with Mr. Tatton that the question of frost, in this country at all events, is not an important one. See also p. 309.

Life of Sewage Farms.

A consideration of far greater moment is that of the permanence, or otherwise, of sewage farms; and, if they do not retain their purifying power indefinitely, how long they may be relied on to do so. The belief is prevalent that all land, even the best, sooner or later loses this power; and that, in common parlance, it becomes "sewage sick." Instances of this were cited by Dr. Barwise.

> "(Chairman)—In your experience, have you ever known land getting sick of sewage?—Certainly I have. I have seen land so sick that when I handed up to one of her Majesty's judges a photograph of the farm in question, he asked me if it was the lake district. The sewage would not go through the land; it simply lay about on this large surface in lagoons of sewage. The effluent simply stank of sulphuretted hydrogen. The Chesterfield Farm, too, has been absolutely sewage sick." [Barwise, 4072.]

Mr. William Edson, the City Surveyor of Ripon, referring to the very successful farm under his management, said he thought that the time was coming when the land would not be able to deal with as much sewage as was then being put upon it, and that an additional area would have to be brought into use. [Edson, 5357, 5358.]

A similar opinion was expressed by Mr. J. E. Sharpe, the Engineer and Surveyor of Otley.

> "I do not say what it will be in a year or two's time, but we cannot get the good effluent from our old land, it is impossible for us to do it." [Sharpe, 12056.]

It is reassuring to find that more optimistic views were held by the majority of the witnesses, several of whom, it will be observed, spoke from wide experience.

> "Then do you believe that the land goes on for ever filtering sewage as efficiently as it does at the beginning?—If the land has been properly attended to, properly worked, legitimately worked, it will go on indefinitely purifying it;

Life of Sewage Farms—*continued.*

and in proof of that I refer you to Croydon, where in 1876, I went with the late Dr. Angus Smith, and analysed the effluent. If you go to that very same area of land and analyse it, it is equally good, therefore there is an instance of land being in use thirty years working efficiently. [Scudder, 664.]

"And you do not think the land deteriorates in any way? —No. [665.]

"Does not get foul?—No." [666.]

"Do you consider that the land will go on for ever cleansing the sewage without suffering itself, provided, of course, you alternate it?—If it is turned over and cultivated and properly managed, it ought to." [Wilson, 1017.]

"And do you consider that the land deteriorates by constant use?—No, I do not. I have been very interested in that. I think a farm properly laid out in the first instance, supposing the land is good, will go on regardless of time. [Chatterton, 6470.]

"Many years?—Yes, and always be sweet and healthy; and I also know that where I have seen land that was once a good bit of loam, but had been disgracefully neglected, and covered with a slimo of sewage sludge probably half an inch or an inch thick, that in excavating that, and in digging out a few spadefuls, that probably four or five or six inches below the surface you could take the soil in your hand and find it perfectly clear and perfectly sweet. I have noticed that nearly every bad sewage farm that I have had to visit was all right underneath, but bad on the top." [6471.]

"Would you say that the length of time that the land has been at work has any effect on it, or that if it is properly managed it can go on indefinitely?—If it is properly managed, and the land is not overdone with sewage, it can go on, I think, indefinitely. We have had farms that have been in operation from ten to fourteen years. Very often one hears that a farm is done, is no use any longer; but in every case it is because too much sewage has been turned on to it, or because the farm has been badly managed." [Tatton, 6618.]

"You would say that if the land is properly treated, and proper care is taken, it would go on practically indefinitely?—That is my opinion and experience, on the whole." [Balfour, 6856.] See also p. 306.

Management of Sewage Farms.

The permanence or otherwise of a sewage farm, as well as the quality of the effluents which it yields, depends to a very great extent on the way in which it is handled, and there can be no question that the low estimation in which these farms are held in certain quarters is largely due to incompetent management. It must be admitted, however, that many farms were from the outset foredoomed to failure by reason of the lack of proper knowledge and skill in their laying out. The land has too often been regarded as an inert mass, to be hewn into such forms as might be convenient for the reception of the sewage, its real nature and functions being utterly disregarded. Terraces have been cut, or levelling operations carried out, whereby the active top soil, "the living earth," has been buried, and the comparatively useless subsoil brought to the surface instead. Underdrains also have been designed and laid by men totally devoid of experience in agricultural underdrainage. But while much depends upon the propor laying out of a sewage farm, its success or failure will, in the long run, turn upon the management which it receives.

> "As regards the failure of many sewage farms,—I could give instances of it. Of course, in some cases, it is due to their having been laid out wrongly, but in most cases it has been due to the improper management of the farms by the men who have been in charge of them." [Voelcker, 10172.]

> "My experience has been that you find very few men who really understand how to apply liquid sewage to land." [Scudder, 681.]

> "Good management is of the greatest importance in any system, and the want of it always leads to failure. Local authorities are often slow to recognise this part, and *loath to give the wages necessary to secure a competent man.*" [Tatton, 6625.] See also p. 308.

"Economy," so-called, is undoubtedly at the root of a large proportion of the failures of sewage farms, while others have been due to the practice, at one time common, of letting the land to farmers to deal with as they thought fit.

> "I should like to state here tho difficulties which the two Joint Committees have in many instances been met with where land has been purchased, namely, that at one time many Authorities sublet the farms which have been obtained for irrigation purposes. Of course these, as soon as they were in the hands of tenants, were farmed more for profit

MANAGEMENT OF SEWAGE FARMS—*continued.*

than for sewage disposal." [*Int. Rep.*, vol. II., p. 51.] See also p. 308.

It is noteworthy that several witnesses held the view that a good farmer is not necessarily a good sewage-farm manager.

> "Would you say that the management of a sewage farm required special knowledge, or that an ordinary farmer could manage it?—Special knowledge." [Chatterton, 6472.]
>
> "You do not think that on a sewage farm an ordinary farmer would understand it?—No; you must have a man who is specially trained. If he is to look after a sewage farm he must have been specially trained for that particular kind of work." [Tatton, 6626.]
>
> "(Professor Ramsay): Would you say that the reason that a farmer is a bad manager of a sewage farm is that his interest lies in producing crops, and not disposing of the sewage?—Yes; there are many times in the year when he does not want the sewage, and if he can shoot it into the watercourse, he will." [Mawbey, 8121.]
>
> "When it is left to a farmer it is not well looked after; that is the rule. Of course, when the farmer does not want the sewage he passes it into the river; when he does want it he puts it on the land, which is not all the year round." [Dr. Williams, 9919.]

It is doubtful, nevertheless, whether that intimate and instinctive knowledge of the nature and capabilities of the soil which characterises the true farmer is not, after all, the most valuable part of the equipment of a sewage-farm manager.

It is only fair to add that the manager is not always wholly to blame for his failure to make the best use of his land, as in some cases he is not allowed to use his own judgment, but is overridden by his committee. A pleasing instance to the contrary is mentioned by Mr. Mawbey:—

> "I started by saying that their first duty was to purify the sewage, and they made me master of the agricultural operations as well as the engineering for a year or two, until we got into first-rate form, and then they allowed the bailiff to manage the sewage himself, subject, of course, to my advising them as their engineer; but we have got an admirable committee, and they always have cleansed the sewage first and then done the best they could with the land and crops afterwards." [Mawbey, 8117.] See p. 319.

The Monetary Aspect of Sewage Farming.

While the habit of subordinating the purification of the sewage to the profitable cultivation of the land cannot be too strongly deprecated, it is interesting to note that this practice derives some sanction from the Reports of previous Royal Commissions, whose recommendations of land treatment appear to have been based to a great extent upon the expectation that a profit might be realised therefrom. The extract, for instance, from the Second Report of the Rivers Pollution Commissioners, issued in 1861, which is quoted by Mr. Adrian, certainly gives as much prominence to the question of utilisation as to that of purification :—

> "In our former report we stated, and we have since seen nothing which should induce us in any degree to alter that opinion, that *to obtain the greatest amount of good from the utilisation of sewage as a manure*, concurrently with the fullest immunity from the evils arising from its discharge into rivers as a noxious and pestilential liquid, to obtain the good and avoid the evil, one only thoroughly efficient mode of treatment could be prescribed, that, namely, of its direct application to land in the liquid form." [Adrian, 45.]

The same Commissioners, in their Third and final Report, made in 1865, submitted certain conclusions, the first of which has already been quoted on p. 4.

> "The second conclusion referred to the different financial results of the land treatment of sewage under different local circumstances. *The third conclusion affirmed that in favourable circumstances there might be a profit, and that, under opposite circumstances, the rate to cover loss need not be of large amount.*" [52.]

Mr. Adrian also, on being asked for his remarks on the Public Health Act of 1875, observed :—

> "The Public Health Act, 1875, being a consolidating Act, contains provisions which, if traced to their origin, are seen to belong to the legislation of some one or other of the three periods already mentioned, and reflect, even in their present context, the prevailing ideas and aims of the period. Thus, when we attempt a broad classification of the law by reference to the powers which it confers, and the restrictions which it imposes, we observe that although the powers as

MONETARY ASPECT OF SEWAGE FARMING—*continued.*

now used may be made to subserve the modern purpose of river protection, *they are fundamentally the outcome of a system of utilisation, or of the profitable application of sewage.*" [80. See also 37.]

Passing on to the actual results from land treatment in their financial aspect, the same witness, replying to Question 150, observed :—

"What I can say is, that in one of the Reports of the Rivers Pollution Prevention Commissioners, they set out a series of balance-sheets, all of which show a profit in the case of the adoption by various towns of schemo of irrigation." [150.]

A striking instance of profitable sewage farming was adduced by Sir Charles Cameron :—

"The Earl of Essex has constantly employed sewage manure since, I believe, 1857, and with an extraordinary degree of success. This nobleman states that he has obtained from sewaged meadows the large produce of 46 tons per acre, whilst from the same quality of meadow, which had not been sewaged, the produce amounted only to from 7 to 8 tons. On the Earl of Essex's farm an application of 270 tons of sewage per acre of mangels produced a yield of 43 tons, or about double the average produced of that crop in England." [Sir C. Cameron, 13035.]

An important experiment on parallel lines tried at Rugby, and mentioned by the same witness, is referred to later (p. 42) in connection with the question of keeping milch cows on sewage farms.

It would be interesting to learn whether the results cited were obtained concurrently with a continuous and satisfactory purification of the sewage, or whether the latter consideration was sacrificed for the benefit of the crops.

It may be observed that the expectation that sewage farming might be conducted at a profit is supported by purely theoretical considerations. Many estimates have been made of the manurial value of human excrement, some of which, ranging from 6*s*. to 10*s*. 10*d*. per head per annum, are cited by Sir Charles Cameron. [13035.]

There are, unfortunately, two grave obstacles to its profitable utilisation. Tho first is the very large amount of water through which it is usually dispersed, and which, while helpful under some conditions, more often swamps the land to an injurious

Monetary Aspect of Sewage Farming—*continued.*

extent. The second, and more serious, drawback is the inability of the land to utilise the sewage during certain seasons, or to receive it without injury to the crops.

It is therefore not surprising that the sanguine hopes which were entertained by early sanitarians have not been borne out in the sequel.

> "The only instance, as far as I know, at the present time, that has recently been put before us as one with any profitable result is, I think, the Norwich scheme. I do not know of any other." [Adrian, 151. See also Barwise, 4067.]

Concrete evidence was given on the subject by Mr. E. G. Mawbey, M.Inst.C.E., Borough Engineer of Leicester, in his replies to questions by the Chairman:—

> "Now, before we come to the experiments at all, I should just like to ask you about your balance-sheet. Did the farm pay its expenses?—No, my lord, there was a very great loss. [Mawbey, 8113.]
>
> "A very great loss?—Yes; thousands a year. [8814.]
>
> "One thousand pounds a year?—Several thousands a year. [8815.]
>
> "On a farm of 1,700 acres you made a loss of several thousands a year?—We made a loss of 6,000*l.* or 7,000*l.* a year; that is, taking everything into consideration." [Mawbey, 8116.]

The case is well summed up by Dr. Voelcker:—

> "In other words, I regard sewage as a nuisance which has to be got rid of, and the point is at what least cost can it be got rid of." [Voelcker, 10163.]

This may be taken as fairly expressing the opinion now held by all who have had to do with sewage disposal. See p. 308.

Cultivation and Cropping.

Utility of Cropping.

The condemnation of sewage farming when conducted with a view to profit as the first consideration does not imply that cropping should be altogether abandoned. On the other hand, its utility as an aid to purification, and particularly to the recovery of land which has become sewage sick, is admitted on all hands.

> "Then you think that the growth of suitable crops actually facilitates the treatment of the sewage?—I am sure it does, in that way." [Dr. Wilson, 6267.]

"And do you consider that the question of crops is important; does land purify better with crops on it?—Well, I think so. Of course, I am not a farmer, but all the farmers that I have ever talked to undoubtedly say so, and I think a sewage farm without crops would be a misnomer. Of course, you have not the whole of your land cropped." [Chatterton, 6467.]

"Well, now, about cropping the land; do you consider that the cropping increases the power of the land for purification?—I do, my lord, and I always advocate and carry this out." [Balfour, 6851.]

"Then do you consider that the cropping of the land affects its power?—I think it is an assistance, so long as you use the right crops." [Tatton, 6614.] See pp. 308, 320.

Suitable Crops. See also p. 310

The witness goes on to specify what crops he has found to be best for the purpose:—

"I think the best of all is rye grass. It absorbs a large amount of moisture, and you get very heavy crops from it; you can get five or six crops of it in the year off the land. Potatoes or corn should not be sown at all." [Tatton, 6614.]

Mr. Tatton is supported both in his recommendation of rye grass and his objection to potatoes and corn by Dr. Wilson, and as to cereals by Dr. Voelcker and Sir Charles Cameron:—

"Rye grass can be treated with sewage almost from the time it is sown, during its whole growth. Mangolds again, and on some farms they treat turnips with sewage pretty constantly until a few weeks before the crop is ripened for removal. Cabbages and such plants can be treated with sewage the whole time, if the sewage does not touch the cabbages. If the cabbages are grown on ridges, so that the sewage does not actually touch the plants, the land on which the cabbages are grown can be used the whole time." [Dr. Wilson, 6258.]

"I do not think, Sir, oats should be grown on the sewage farm at all; I think it is a crop that should be forbidden on a sewage farm." [6260.]

"Potatoes is another crop that sewage should not be put upon; it may be, in very rare circumstances, necessary to grow such a crop as oats and potatoes; but it can only be where there has been some neglect, and the land has become very sewage sick." [6263.]

Suitable Crops—*continued.*

"Practically, the land on which cereals are being grown cannot be used for the purification of sewage?—Where cereals are grown for corn?" [Voelcker, 10190.]

"Yes?—Yes, that is so." [10192.]

"Land of any kind under cereals cannot constantly be the scene of sewage irrigation, for during the long period of the year devoted to the preparation of the ground a dry and easily pulverulent condition of the staple is desirable; and during the ripening of the crop, heat and a very moderate degree of humidity are necessary. It is clear, then, that cereal crops could only be benefited by very moderate doses of sewage applied at only certain periods of the year. Still, where sewage is available, I believe that both white and green crops would be largely served by its use." [Sir C. Cameron, 13035.] See also pp. 310, 319.

Tillage v. *Pasture.*

Sir Charles Cameron expressed an opinion which is on the whole somewhat hostile to cultivation. It is, however, favourably regarded by Mr. Santo Crimp and Mr. Tatton:—

"With respect to the kind of crops to which sewage is most adapted, it appears to be admitted on all sides that the natural and artificial grasses are those that have hitherto been most benefited by its application. There are, however, on record the results of experiments which go far to prove that sewage may, under certain circumstances, be usefully applied on tillage farms. . . . As a general rule, however, I believe that town sewage, which is an excessively dilute solution of manure, cannot be employed to any great extent on tillage farms, more especially on those that are not thoroughly drained." [Sir C. A. Cameron, 13035.]

"Do you consider there is no difference whether the land is grass or arable land?—I think that where you get anything like these quantities that I am referring to, 7,500 gallons per acre per day, the crops would be very much limited in character; you will be practically limited to rye grass, to mangels and perhaps to cabbages, because of the large volume of liquid that is applied." [Crimp, 1579.]

"You do not think that if it was left in permanent pasture the land would be able to take up as much sewage?—Oh, nothing like it." [1582.]

"I have observed with permanent pasture, where some

large quantities of sewage have been applied, that the finer grasses are altogether destroyed. [1584.]

"Are altogether destroyed?—Altogether destroyed, and in place of the fine grass you get a coarse, rank grass, with an immense amount of coltsfoot, and so on." [1585.]

"I should say, however, that pasture land will not deal with the volume that arable land will deal with, owing to the fact that the surface of the pasture land cannot be ploughed and aërated: conditions of great importance to the success of a sewage farm." [Tatton, 6632.]

Willows.

The opinions as to willows are also conflicting:—

"Willows do very well indeed; we have several farms in the West Riding; one the Commission saw at Ripon, and the results there have been very good. At Pateley Bridge and Otley there are other willow plots, and they seem to do very well." [Dr. Wilson, 6265.]

"In many places they use willows, put down willow beds; but I do not much like willow beds myself, because when they grow up they keep the air from the soil and make the proper supervision of the surface a difficult matter, so that weak places caused by settlement or by rats, moles, &c. are difficult to detect." [Tatton, 6615.]

It may be mentioned also that sewage-grown willows are apt to be brittle.

Milch Cows and Oxen on Sewage Farms.

Special attention was paid by the Commissioners to the question of keeping milch cows and oxen on a sewage farm, particularly with regard to the former.

Several witnesses were examined on the subject, and the general drift of their evidence may be gleaned from the following extracts:—

"Would you have any opinion as to whether it is right to keep milk cows on a sewage farm?—I think, yes, if the sewage farm is most carefully worked. Milch cows, of course, must never be put near the grass which has recently been treated with sewage, because of the dauger of putrescent matter and pathogenic germs in the grass itself; but I think it is quite evident, from the experience at Birmingham of the sewage farm there, that with proper

MILCH COWS AND OXEN ON SEWAGE FARMS—*continued.*

care milch cows can be kept upon a sewage farm with safety." [Adeney, 2525.]

"Should you say that it was right to keep milk cows on a sewage farm?—I do not see any objection if the cows are kept up. [Barwise, 4059.]

"You do not think there is danger of the spread of typhoid fever, say, from the milk of these cows, which might possibly have access to sewage either as a liquid to drink or as forage?—In my answer to the question whether it was right to keep milk cows on a sewage farm, I meant the cows kept constantly under cover; I meant the cows kept constantly in their cows sheds. I was thinking, then, particularly of the Birmingham sewage farm, where they have some 400 or 500 cows constantly under cover. I was a practitioner in Birmingham for some time. The milk from that farm was supplied to people in my own district, and I certainly should have known if there was any reason to suspect it." [4060.]

"(Mr. Power): In the case of the milch cows drinking from a sewage effluent, did it affect the quantity of milk they yielded or make them seriously indisposed in some other way?—I believe this is the method of hurting them, Sir. It sets up diarrhœa, and it makes the cows drop their calves and brings them into a low state of health, and I believe they are very apt to take tuberculosis." [Dr. Wilson, 6284.]

Further information as to the health aspect of the case will be found in answers 657 *et seq.*, 1021-2-3, 3006, 6274-5-6-9, 6287 *et seq.*, 9744, 10165 *et seq.*, 10222. See also p. 308.

Some interesting evidence as to its financial side was given by Sir Charles Cameron:—

"In 1861 a Royal Commission was appointed to experiment on the sewage of Rugby. The object was to determine the quantity and composition of grass produced on land, a portion of which was to be manured with sewage, and another portion to remain unmanured. Fifteen acres were divided into three equal parts—one for grass on which cows were to be fed, another for grass on which oxen were to be fed, and the third was to be meadowed. Each of these five-acre divisions was further sub-divided into four plots, one of which was left unmanured, and the others received respectively different quantities of sewage. Some of the results obtained are tabulated in the table on the opposite page.

MILCH COWS AND OXEN ON SEWAGE FARMS—*continued.*

Producc given to Oxen.

Plot.	Sewage required per annum.	Actually applied to end of October.	Total grass per acre.				Increase of grass per 1,000 tons of sewage.			
			tons	cwts.	qrs.	lbs.	tons	cwts.	qrs.	lbs.
1	—	—	9	5	3	5	—	—	—	—
2	3,000	1,872	14	16	3	8	2	19	1	7
3	6,000	4,423	27	1	0	10	4	0	1	9
4	9,000	6,153	32	16	3	8	3	16	2	9

"On the grass given to the milch cows the effects of the sewage were still more favourable, as will be seen in the following table:—

Produce given to Milch Cows.

Sewage applied.	No. of weeks the produce kept a cow.	Gallons of milk per acre.	Value of milk at 8*d.* per gallon.			Value of milk from increased produce of 1,000 tons sewage.		
			£	*s.*	*d.*	£	*s.*	*d.*
—	19	321	10	14	3	5	0	0
1,387	40·9	570·7	19	0	6	5	19	10
2,804	58·8	820·4	27	6	11	5	16	8
4,226	68·9	961·3	32	0	10	5	0	11

"In these trials it is shown that the application of sewage was attended by a very great increase in the produce of grass. 'Deducting the value of the milk from the grass of the unsewaged from that of each of the sewaged acres, reckoning it at 8*d.* per gallon, it appears that where about 1,400 tons of sewage were applied during the seven months, the produce calculated for each 1,000 tons of sewage actually applied gave an increased amount of milk to the value of £5 19*s.* 10*d.*; where twice that amount of sewage was applied, £5 18*s.* 8*d.*; and where three times the quantity, £5 0*s.* 11*d.*' The value of the milk obtained from an acre of unsewaged grass was only £10 14*s.* 3*d.*, whilst from the most highly sewaged grass the value of the milk amounted to no less than £32 0*s.* 10*d.*" [Sir C. Cameron, 13035.]

CHAPTER III.

Question 1.

Are some sorts of Land unsuitable for the Purification of Sewage?

In the preceding chapter testimony is quoted from a large number of sources to the efficiency of land as an instrument for purifying sewage. It is significant that the witnesses, with hardly an exception, took care to qualify their answers with the proviso that the land must be suitable for the purpose.

That some land is not suitable, and that the requisite area of land is often unobtainable, is abundantly shown by the following extracts from their evidence:—

> "There are, however, cases where suitable land cannot be obtained, or only at great cost, and then the Local Government Board might well modify their hard-and-fast rule." [Tatton, 259.]
>
> "With regard, then, to the land filtration, it is unfortunate that land of a suitable character and area necessary in order to effect what I say can be brought about, and is brought about in certain places, namely, a satisfactory effluent, especially in the case of large towns, is difficult to acquire, and where possible in many cases the cost is often excessive, and therefore in many instances artificial filtration has to be resorted to." [Roscoe, 3511.]
>
> "There is no doubt that land filtration is an excellent system where you can adopt it, but I say there are a great many cases in which you cannot adopt it." [3709.]
>
> "One general conclusion that I have come to is, that land which will purify sewage is much rarer than is generally supposed, at any rate so far as the county of Derby is concerned. I have here a geological map of the county, a reference to which will show that we have little land in Derbyshire which is really suitable." [Barwise, 4022.]
>
> "I think, my lord, lands of all kinds will not naturally properly purify domestic sewage, only land more or less

porous in quality and then proportionately in quantity." [Balfour, 6842.]

"In several of our long, narrow, and crooked mining valleys it is impossible to acquire a sufficient area of suitable land within a reasonable distance, except in very large centres." [Dr. Williams, 9819.]

"Of course, there are frequently cases in which it is practically impossible to obtain land?—Yes, that is so. [Voelcker, 10177.]

"Or if the land can be obtained, it is not of a suitable character?—No, not of a suitable character." [10178.]

The three kinds of land more particularly referred to as unsuitable were peat, chalk, and clay.

Peat.

"I should say that peaty, boggy land—all land so situated that the level of the subsoil water is near the surface—that is to say, very near the surface—will not properly purify domestic sewage." [Chatterton, 6425.]

"You may have land which is peaty—very unsuitable indeed." [Voelcker, 10173.]

"Peat land is quite unsuitable for broad irrigation, as without efficient drainage the peat becomes waterlogged; it can only be used, therefore, on the intermittent system. The Altrincham and Wilmslow (southern) farms both contain a considerable amount of peat, and are underdrained." [Tatton, 6632.]

"Peat land you describe as unsuitable for broad irrigation, but suitable for intermittent filtration; have you any instance of peat land?—Yes, Wilmslow. Wilmslow is one instance where it is underdrained. They do fairly well there, but they do not deal with a large volume of storm water. . . . Peat land must be underdrained, because being so absorbent, unless it is you would never get rid of the water from it—it would be always in a spongy condition. [6635.]

"And underdrained peat land is suitable for farm treatment?—Yes, it is." [6636.]

It will be seen that peat soils are not absolutely condemned except for broad irrigation, or where the level of the subsoil water is near the surface; the latter difficulty, as pointed out by Mr. Tatton, being generally curable by underdraining. See also p. 314.

Chalk.

The objection to chalk is based, not on any incapacity of its surface-soils for treating sewage, but on the extreme permeability of the material and its liability to fissures, through which it is apprehended that imperfectly purified sewage may reach the water-supplies which are frequently drawn from this formation. Dr. Barwise was questioned on the subject by Sir Richard Thorne:

> "Do you know what the water companies say of the chalk ranges north and south of London?—Oh, I expect they object to sewage farms upon them, and so should I." [Barwise, 4126.]

Within recent years the writer has known one scheme of sewage disposal thrown out and another greatly obstructed, on the ground that some distant wells might be polluted by the sewage. See also p. 314.

Clay.

> "But when you come to clay—clay land ought to be entirely avoided, because on clay land the volume of effluent which you can deal with is so small that it has practically no value as a filtering medium." [Scudder, 609.]
>
> "I consider clay land is unsuitable under any conditions, for this reason, that you cannot get what I call a legitimate volume of effluent through it; you cannot filter a sufficiently large volume to make it of practical use." [674.]
>
> "And you do not consider that the fact of its being treated for arable purposes—broken up, ploughed up—makes it an effective filter?—No, I do not, my lord." [678.]
>
> "And are you of opinion that the clay land is very unsuitable for sewage treatment?—Yes, I am, unless it is specially treated." [Naylor, 962.]
>
> "Do you agree with what we were told yesterday, that clay land is almost useless for the purpose?—Certainly, my lord." [Dr. Wilson, 1004.]
>
> "Then, on the opposite side, you may have land which is clayey—equally unsuitable. Clay, of course, is open to the great objection that in hot weather it cracks. If you drain it underneath you will get the sewage running straight down to the drain without going through the land at all." [Voelcker, 10173.]

On the other hand, positive evidence was submitted by several witnesses, whose opinions cannot be ignored, that all land, not

CLAY—*continued.*

excepting clay, possesses in a greater or less degree the power of purifying sewage.

"On page 2 of your evidence you do not absolutely condemn clay land as useless for filtration?—Oh, certainly not!" [Latham, 4665.]

"Will you give us your opinion whether land of all kinds, when used alone and without the artificial addition of chalk, cinders, or other material, will properly purify domestic sewage?—I am of opinion that land of all kinds will purify domestic sewage. [Tatton, 6579.]

"Should you say land of heavy clay would purify sewage?—Yes, it will; but you must have a large area of the land, and you must use it on the broad irrigation principle and allow the sewage to flow over the surface, as a small quantity only will filter through." [6580.]

"Clay land can only be used on the broad irrigation system." [6632.]

"(Chairman): Do you consider that all kinds of land will purify sewage?—As far as I know, everything short of rock. [Strachan, 7623.]

"You do not think there is any clay so hard that the sewage would flow over it without getting clogged?—I have never met it. I have never met with clay on the surface, there is always some soil—always some." [7624.]

"But I think that all lands are capable, more or less, of effecting very considerable purification if they can be mechanically adapted to it by proper cultivation and so forth. After all, the purification goes on not in the lower layers but in the upper layers, and if you can by cultivation get your soil to act as a filter, and as a purifying medium, I think that even on a soil that you would not take by choice you can effect a very great improvement, *but you may have to use a much larger area of land.*" [Voelcker, 10173.]

"I should doubt very much whether there were many cases in which the land was not very suitable, or, at all events, where land that could be utilised could not be found." [10181.] See also pp. 314 *et seq.*

The conflict between these two schools is more apparent than real. The truth appears to be that the difference between the suitable and unsuitable lands, so far as relates to their purifying power, is a difference not in kind, but in degree; the defect of the latter consisting, not in sheer inability to purify sewage, but

CLAY—*continued.*

merely in their incapacity to deal with it in such quantities as to render it economically possible to use them.

Thus, Mr. Santo Crimp, after describing what he regarded as the best kind of soil, went on to say—

> "We get an infinite series of gradations between that and the soil where you should draw the downward limit, and we usually regard clay soils as being at the other extreme." [Crimp, 1576.] See p. 314.

An instructive instance of good work done with the soil which stands lowest in Mr. Santo Crimp's scale of efficiency is supplied by Mr. Mawbey in his evidence concerning the sewage farm at Leicester. The soil,

> "with the exception of thirty acres of it, is clay under the topsoil, which is about six inches to a foot thick. There is a layer of stiff yellow clay about two to three feet deep overlying blue boulder clay for a great depth." [Mawbey, 8094.]

Mr. Mawbey described in considerable detail [8095] the means by which he succeeded in turning this unpromising material to good account. He was then asked by the Chairman :—

> "Could you tell us to what extent the broad irrigation on your clay land has been successful in purifying the sewage? —For several years effluents were uniformly satisfactory, and quite equal to acknowledged satisfactory standards. The following analysis, taken in October and December, 1891, namely, twelve to fifteen months after the farm had been in operation, is a fair average :—
>
> Albuminoid ammonia, ·09 grain per gallon,
>
> and
>
> Oxygen absorbed, ·562 grain per gallon." [8110.]

The working expenses are not stated, but Mr. Mawbey mentions the loss on the farm, "taking everything into consideration," as from £6,000 to £7,000 a year. [8116.]

This is admirable as an illustration of what can be accomplished even with the worst kind of land, given plenty of it, sufficient fall, a capable manager, and last, but not least, the determination to succeed at all costs. It will, however, hardly be regarded as an experience to be emulated, and most people will be disposed to agree in the main with the opinions expressed by Dr. Wilson and Mr. Scudder, and the conclusions arrived at by the Commissioners themselves :

> "I think that some kinds of land are quite unsuited for

CLAY—*continued.*

purifying sewage. If you have a sufficient area, any kind, I believe, of soil will purify sewage; *but the area required of certain clay lands is so enormous that it is impracticable to purify sewage upon such land.*" [Dr. Wilson, 6136.]

"When you come to estimate what area of clay land will be necessary, *it is ridiculous to ask them to acquire that area of land; they cannot get that area of land.*" [Scudder, 675.]

The opinions arrived at by the Commissioners, after considering the foregoing and other evidence on the subject, are set forth in the following passages from their Interim Report:—

"13. . . . We have received evidence from a number of witnesses who have had much experience of sewage treatment. Almost without exception their testimony is to the effect that peat and stiff clay lands are unsuitable for the purification of sewage.

"14. Our own officers have made a large number of analyses of effluents from well-managed farms with different classes of soil, and their results support this general opinion.

Conclusion 1.

"15. We doubt if any land is entirely useless, but in the case of stiff clay and peat lands the power to purify sewage seems to depend on the depth of the top soil.

"There are, of course, numerous gradations in the depths of top soil which are met with in nature, and it is not easy to draw the line between lands which contain a sufficient depth to justify their use and lands which do not.

"We are, however, forced to conclude that peat and stiff clay lands are generally unsuitable for the purification of sewage, that their use for this purpose is always attended with difficulty, and that where the depth of top soil is very small, say six inches or less, *the area of such lands which would be required for efficient purification would in certain cases be so great as to render land treatment impracticable.*"

[*Interim Report, p. ix.*

This finding of the Commissioners releases engineers from the intolerable position in which they were formerly placed, of having to prescribe the same remedy in every instance, in utter disregard of circumstances. If, without disrespect to the medical profession, one can conceive of a physician bound by such a rule,

CONCLUSION 1.—*continued.*

he would at least have the satisfaction of being able to depend with some degree of certainty on having his prescriptions made up with materials of approximately uniform composition. The unfortunate engineer had not even this security, for only too often he knew at the outset that the land which he was forced to prescribe was practically useless for the purpose in view. It is recorded that on one occasion where the land (the best that could be found in the neighbourhood) was a stiff clay, hopelessly waterlogged and liable to flood, the inspector who held the inquiry, after gazing long and earnestly into the trial pits, turned away with the brief but pertinent comment, "Well, it's 'land'!" The letter of the law was satisfied.

That the various Royal Commissions which have previously inquired into the subject, and on whose findings the rule insisting on land treatment was based, did not regard their recommendations as binding in all cases and for all time, is shown by several passages in Mr. Adrian's evidence:—

> "At the same time, the Commissioners (appointed in 1857) recognized the importance of the consideration that other means of dealing with sewage should be at the command of such towns as from local circumstances might be unable to adopt the liquid method of distribution." [Adrian, 45.]
>
> "The results of experience and of the investigations of the subject by the most competent authorities, have been strongly and almost universally in favour of the application to land as in every respect the best and most advisable mode of treating sewage *when circumstances will admit of its use.*" [Royal Commission of 1882.]

And again:—

> "There was one other conclusion which, perhaps, deserves quotation. This was: 'That there is good ground for believing that the methods yet proposed for dealing with sewage are not the best that can be devised, and that further investigation will probably result in the discovery of processes more thoroughly equal to the suppression of the nuisance, and at the same time calculated to give more valuable products.'" [Adrian, 37.]

It will hardly be contended that the expectation expressed in the concluding sentence has yet been realized. How far the remainder of the prediction has been justified will be considered in the next chapter.

CHAPTER IV.

THE PURIFICATION OF SEWAGE IN ARTIFICIAL WORKS.

HAVING arrived at the conclusion that land treatment is, in certain cases, impracticable, the Commissioners pass on to their second question.

Question 2.

"IS IT PRACTICABLE UNIFORMLY TO PRODUCE, BY ARTIFICIAL PROCESSES ALONE, AN EFFLUENT WHICH SHALL NOT PUTREFY AND SO CREATE A NUISANCE IN THE STREAM INTO WHICH IT IS DISCHARGED?

"The following general classification will serve to show the nature of the artificial processes to which we refer:—

Closed septic tank and contact beds.
Open septic tank and contact beds.
*Chemical treatment, subsidence tanks and contact beds.
Subsidence tanks and contact beds.
Contact beds alone.
Closed septic tank, followed by continuous filtration.
Open septic tank, followed by continuous filtration.
Chemical treatment, subsidence tanks and continuous filtration.
Subsidence tanks, followed by continuous filtration.
Continuous filtration alone.

* The expression 'subsidence tanks' is intended to denote tanks which are used in such way that little or no 'septic' action is produced." [*Interim Report*, p. 9.]

Bacterial Processes not Artificial.

The phrase "artificial processes" is somewhat misleading, for of the ten combinations cited there are only two which can fairly be described as artificial, and those in part only. With these exceptions all the processes considered are essentially natural, the object in each being to give natural agencies the freest possible play.

The idea that the processes in question are artificial is strongly combated by Dr. Houston in his second report to the London County Council on the bacteriological examination of London sewage and effluents; and Dr. Clowes, in his fourth report to the Council, repeatedly speaks of the "bacterial or *natural* treatment of sewage."

The classification of these processes as "artificial" would be of less importance were it not for the use which has been made of the term in the attempt to decry the new processes in favour of land treatment, which is held up by contrast as "natural." A moment's reflection will show that the distinction thus sought to be drawn is not a sound one. It can hardly be regarded as a "natural" proceeding to flood land with dirty water to the extent of twenty or thirty times the amount of the rainfall. The only mode of dealing with sewage which can strictly be described as "natural" is to do away with it altogether, and apply its constituents separately to the soil. Sir Charles Cameron reminds us, delicately enough, of the way in which this is done in China (13035); and an example nearer home is to be found in Dr. George Vivian Poore's charming little essay on the "Living Earth." Apart from its literary charm, it is refreshing to turn from the dreary record of sewage farms which are little more than sinks for the ratepayers' money, to Dr. Poore's interesting recital of how crops to the value of 70*l.* per acre were raised in his own garden by the skilful utilisation of the slops and excreta from his own house and cottages. One is, however, forced to admit that the high ideal established by Dr. Poore is only to be reached in the most exceptional cases, and that so far, at all events, as our larger towns are concerned, for better, for worse, the water carriage system has come to stay.

Work done in Two Stages.

It will be noticed that of the ten processes referred to by the Commissioners only two, the fifth and the last, consist of single elements. In reality this is true only of the last, for contact beds, wherever they occur alone, are used in two or more series, and it is recognised that the work which is done in the first series is of a different nature from that done in the second and subsequent ones.

This dual treatment of sewage is necessitated by the fact that its purification comprises two distinct classes of operations; the first being the elimination of the solid matter which it contains, and the second the conversion into stable and inoffensive forms of the dissolved polluting matter. These two sets of operations are generally carried out independently, the removal of the solids being (with rare exceptions) the first to be put in hand.

The solid matter in sewage is of two kinds, mineral and organic, the first category comprising the débris from roads and paved surfaces, and the second solid excretal matter, scraps of vegetables and meat, paper, cloths, candle ends, matches, and the various little etcetera which find their way into the household sinks. The mineral solids, with the exception of the finely-divided mud from road surfaces, readily settle in the grit chambers which are usually provided for their reception, and the larger solids are easily removed by screening. After this has been done, there still remains in the sewage a quantity of suspended matter, ranging up to 100 or 200 grains per gallon, or even more, which is too finely divided to be intercepted by screens, and will not readily settle. Much of it, however, may be removed by a process of deposition or "sedimentation," as it is sometimes called, in tanks sufficiently large to permit the liquid to come very nearly to rest, such tanks being often fitted with "scumboards" to arrest floating solids and the scum which forms on the surface.

CHAPTER V.

CHEMICAL PRECIPITATION.

The deposition of the solid matter in sewage is often assisted by the addition of chemicals, the process being then known as "chemical precipitation." It may be noted here that the action which takes place differs from ordinary chemical precipitation, the object of which is to throw down in a solid form substances previously dissolved in the liquid, in that the action of the chemicals is directed wholly or mainly to the settlement of the solid particles already present as such.

That precipitation is an efficient means for freeing sewage from solid matter in suspension is recognized on all hands; but considerable difference of opinion has been manifested as to whether or not any considerable portion of the dissolved polluting matter is removed thereby.

> "The Rivers Pollution Commissioners, after an examination of the various processes of chemical precipitation then known, came to the conclusion that the average amount of purification was 28·4 per cent. organic carbon and 36·6 organic nitrogen." [Ridcal, 4135.]

Evidence in favour of precipitation was given by several witnesses, among others Mr. W. C. Sillar, a director of the Native Guano Company. After enumerating the precipitants used, Mr. Sillar goes on to say:—

> "When the sewage thus treated passes into the settling tanks precipitation occurs, which not merely deposits the grosser suspended matters, but a large proportion of the dissolved impurities which have attached themselves, both chemically and mechanically, to the clay, carbon and blood. The resulting effluent water is rendered fit to be discharged into ordinary watercourses." [*Interim Report*, vol. II., p. 298.]

Mr. Sillar quotes certain conclusions arrived at with respect to

his process by Sir William Crookes, F.R.S., Professor Dewar, F.R.S., and Dr. Tidy, among which occur the following:—

> "1. That the A. B. C. process produces a clear effluent, free from suspended matter, and devoid of smell.
>
> "2. That the effluent is uniform, notwithstanding the very varied nature and concentration of the sewage.
>
> "3. That as the strength of the sewage increases the precipitation is more complete.
>
> "4. That the process removes over 80 per cent. of the total oxidisable organic matter.
>
> "5. That it precipitates 60 per cent. of the organic matter in solution, and of the residue left in the effluent at least two-thirds are non-albuminous, and therefore of a nature less liable to putrefactive and other changes." [*Interim Report*, vol. II., p. 300.]

Analytical figures are also given, showing the average amount of albuminoid ammonia in weekly samples as 0·204 parts per 100,000 for 1898, and 0·224 for 1899.

Mr. Thomas Stenhouse, F.I.C., F.C.S., Public Analyst of Rochdale, mentioned a reduction of 52 per cent. in oxygen absorbed as a "typical result of treatment with alumino-ferric" [12371], and Mr. C. F. Wike, City Surveyor of Sheffield, gave the amount of purification effected by precipitation as 50 per cent. [14701.]

On the other hand, Mr. Santo Crimp, speaking as an engineer from a wide experience of sewage works, says:—

> "It is now admitted by everybody that a chemical process does practically nothing beyond throwing down suspended matter. There is, I believe, a small reduction of organic matter, but in practice I do not think it is worth considering." [Crimp, 1674.]

Mr. Naylor, in the course of his examination by Professor Foster, indicates one cause of the uncertainty which prevails on this point:—

> "Yes, I am quite aware that in the case of sewage particularly, organic matter exists in a sort of colloidal state, which is neither in solution nor suspension, and that aluminium hydrates or aluminium oxides have the power of carrying it down . . . . . I have made experiments with the idea of finding out to what extent organic matters in solution can be precipitated, and I have always been com-

Chemical Precipitation—*continued.*

pelled to state in the witness box that it does not amount to a very great deal; at any rate, certainly it has not been sufficient to dispense with further treatment. Precipitation cannot be relied upon alone." [920.]

Mr. Naylor's opinion is supported by that expressed by Mr. Dibdin, on page 31 of his "Purification of Sewage and Water," as follows:—

"Chemical precipitation, so far as it is applicable to sewage, mainly effects one thing only, and that is the separation of the suspended matters from the liquid matters. Under favourable circumstances a certain percentage of the dissolved impurities may be carried down, but in no case is this fully secured. Whatever may be claimed to the contrary, there is not a workable process of precipitation yet invented which will do more than effect a separation, for all practical purposes, of the solid from liquid matters. That is to say, that if a thoroughly good effluent, as we now understand it, be required, the 'tank' effluent, as it is called, obtained by chemical precipitation, must be submitted to further treatment."

(See also 2384, 3833, p. 304, 7761, 14699, 15466, 15586.)

Before leaving the question of whether or not chemical precipitation effects any appreciable reduction of the dissolved polluting matter, it will not be amiss to draw attention to two or three considerations which may throw some light upon the discrepancy of opinion which prevails on the subject. The first is the constantly varying composition of sewage, and the consequent difficulty of ensuring that the samples taken for analysis before and after treatment do actually represent the same liquid. The second is the fact, drawn attention to by Mr. Scudder [526], that a portion of the solid matter dissolved in sewage often separates out spontaneously on standing.

It may further be pointed out that all sewage which is not actually sterile is normally subject to changes brought about by bacteria, and unless (which rarely happens) the chemicals used for precipitation are of such a kind as to inhibit bacterial action, and are added in such quantities as to do so immediately, a certain amount of purification will inevitably occur, not, however, by reason of the addition of the chemicals, but rather in spite of them.

Capacity of Precipitation Tanks.

The capacity of precipitation tanks, according to Mr. Chatterton, should be not less than 50 per cent. of the daily dry-weather flow, or 75 per cent. if the place can afford it. [6461.] Mr. Tatton recommends a larger provision :—

> "On the question as to the size of purification tanks I am strongly of opinion that a great advantage is to be gained by having the tanks of large capacity; the advantage quite outweighs the extra cost entailed in their construction. They should have a capacity of not less than the volume of the dry-weather flow in twenty-four hours, and twice this capacity if six times the volume is dealt with." [6587.]

From a subsequent answer it would appear that he did not refer exclusively to precipitation tanks :—

> "If your tanks are of large capacity you can save the cost of chemicals; you can let the sewage pass through the tanks, and the solid matter settles out. On the other hand, if your tanks are not of large capacity, you must use chemicals in order to get the solid matter out more quickly." [6592.]

At Chorley, to treat a dry-weather flow of from 600,000 to 700,000 gallons, tanks are provided of a total capacity of 1,120,000 gallons, or from 1·6 to 1·9 days' flow. [Hibbert, 7761.]

The dry-weather flow at Salford, when the tanks were laid down, was estimated at 7,000,000 gallons per day [15410], and the tanks hold 5,250,000 gallons, or three-quarters of the daily flow. [15422.]

As to the method of working, Sir Henry Roscoe recommended emptying the tanks and removing the sludge every day. [3700.] Mr. Tatton was of opinion that they "should be constructed so that they might be used either on the quiescent or continuous flow system." [6587.]

At Chorley, Mr. Alderman Hibbert has

> "Experimented with continuous and quiescent flow in precipitation tanks, and has come to the conclusion that it is impossible with continuous flow to get as good results as from quiescent flow, either in quantity of water treated or quality of the final effluent, if the said effluent has to be treated on a filter with a top stratum of sand." [7761.]

Relative Value of different Precipitants.

"What kind and quantity of chemicals give the best results?—The chemicals chiefly used as precipitants are lime, lime and sulphate of iron, alumino-ferric, the latter also sometimes used in conjunction with lime. Which of these is the most suitable is a chemical question, and can only be ascertained by experiment on the particular sewage to be treated; the manager of a sewage works, if he is a man of intelligence, will soon ascertain what suits his particular case best. When the sewage contains manufacturing waste it will vary considerably from hour to hour, and great attention will be required in adapting the chemicals to suit it. In these cases it is often an advantage to use two chemicals, such as lime and sulphate of iron, one being an alkali and the other an acid." [Tatton, 6586.]

Dr. Adeney, D.Sc., F.I.C., speaks with approval of "oxanite":—

"It consists of a crude sulphate of manganese mixed with the higher oxides of that element. It can be sold in small lots at 45*s*. per ton at works." [2384.]

The precipitants used by the Native Guano Company are described by Mr. Sillar, their director, as consisting principally of:—

"Clay,	Blood, and
Carbon,	Salts of Alumina.

"Should the sewage be too acid some alkali would be used to neutralise it; should it be too alkaline a little acid is added. These substances are used in the following manner: first, the sewage is treated with a triturated mixture of clay, carbon, and blood, which at Kingston is added to it in the pumpwell before it is raised to the tank level; it is considered preferable to add this mixture to the sewage at the earliest possible stage after it reaches the works. These substances together act as deodorants and purifiers. Subsequently a solution of alumina is added in the channel leading from the pump delivery to the tanks. The exact proportions in which these substances are mixed and added to the sewage vary with the strength of the latter, but the average

proportions may be inferred from the following figures for the materials used at Kingston :—

"Clay, carbon, blood, and salts of alumina } Grains per gallon, 50."

[*Interim Report*, vol. II., p. 298.]

Mr. Hugo Wollheim, the inventor of the "Amines" process, described his precipitant as follows :—

"My invention relates to a new gaseous re-agent, to which the name 'Aminol' has been given, and which has been found to be antagonistic to the existence and propagation of every species of bacteria occurring in sewage and other foul or waste liquids. It is produced by the action of alkalies, such as lime, on certain organic bases belonging to the chemical group of 'amines,' *e.g.*, tri-methyl-amine $(CH_3)_3N$, and which are contained in many objects occurring in nature, and also in some waste products. In the 'Amines' process, the re-agent is produced by mixing with milk of lime a small quantity of the waste brine from the curing of herrings, herring-brine being at present the cheapest and most abundant waste product available, and which will yield the organic bases referred to in sufficient quantity for all requirements. The process is applied in the same manner as precipitation processes generally, viz., by adding the said mixture of milk of lime and herring-brine to the sewage during its flowing to the settling tanks; it can, therefore, be applied at the very shortest notice, and without any additional plant at any existing works where there is proper tank accommodation." [*Interim Report*, vol. II., p. 304.]

At the Chorley Works, where excellent effluents are said to be uniformly obtained, ferrozone, ferral, and alumino-ferric have been used in turn, the second being preferred. [Hibbert, 7761, 7771.]

Dr. Voelcker favours lime :—

"Of all the systems of precipitation, I still think the simplest one is that of lime precipitation. I have had to deal with other systems in which sulphate of alumina and other chemicals have been used in conjunction with lime, and although there may occasionally be cases, especially where manufacturing refuse comes in, in which these can be usefully employed, on the whole I still consider that the simple precipitation with lime is the cheapest and the most easily dealt with." [10164.]

Alumino-ferric is used in many places with considerable success, but it is not regarded with much favour by Mr. Dibdin:

> "The results further demonstrate the striking superiority of iron over alumina for sewage purification. By the use of iron sulphate in conjunction with lime, as much work is effected (on the basis of the London sewage) for £31,000 per annum as would be obtained by an expenditure of £82,000 for alumina and lime." [Dibdin, "Purification of Sewage and Water," p. 36.]

INFLUENCE OF PRECIPITATION ON SUBSEQUENT PURIFICATION.

Dr. Percy Frankland points out that "there is one point of view from which precipitation is of great efficiency, and that is in respect of the removal of micro-organisms." [9927.] On the other hand, the removal of the micro-organisms appears to be a hindrance to the subsequent purification. Mr. Santo Crimp, speaking of his experience at Wimbledon, said:—

> "Well, I do believe this: that the more chemicals you use in precipitating the solid matters, the more difficult it is to purify the effluent afterwards." [1737.]
>
> "I am certain, from the results, that the absence of nitrification after lime treatment has been due to a sterilizing action; that has been met with over and over again during the last few years." [Ridcal, 4217.]

Mr. Baldwin Latham, speaking of the Friern Barnet filters, says:—

> "The sewage there is chemically treated, but the amount of chemicals used, sulphate of alumina and lime, is very small, and costs about one penny per head per annum on the population. Experiments made on these filters show that very great care is required in working a filter, *for an excess of chemicals will put the filter out of work.*" [4505.] See also 4477, 4550.

On the other hand, Mr. William Brown, representing the Reeves Chemical Sanitation Company, refers to chemical treatment under the Reeves system as "increasing the purifying power of the land" [*Interim Report*, vol. II., p. 296]; and Dr. Percy Frankland, when asked whether "chemical precipitation would bring about antiseptic conditions which would vitiate the action of the filters afterwards," replied, "Oh, no; if the amount

of chemicals is that which is usually applied, I do not think they would have any appreciable antiseptic action at all." [9967.]

Sludge.

Chemical precipitation always results in the production of a large amount of sludge, consisting of the solid matter thrown down from the sewage, the chemicals employed, and water; the moisture present being in general about nine-tenths of the whole. The weight of wet sludge per million gallons of sewage is mentioned as 26 tons at Salford [*Ib.*, p. 306], 21 tons at Manchester [5450], and 60 tons at Chorley [7986].

The introduction of chemical precipitation, like that of sewage farming, was largely inspired by the hope of profit. It was expected that the fertilizing constituents of sewage, to the value of which reference has already been made, might, by the addition of a small quantity of a suitable precipitant, be recovered in a solid form. If this could have been done, it would undoubtedly have been a great step towards the profitable employment of sewage; for, in the first place, it would have done away with the necessity for flooding the land with the liquid; secondly, the concentration of the manurial matter in small bulk would have enabled it to be stored and applied to the land at those seasons at which the greatest benefit would be derived from its use; and last, but not least, its portability would have greatly extended the field for its employment, which is otherwise limited to the area which the sewage can conveniently be made to command. The fallacy of the hope thus entertained is due to the failure to take into account the fact that something like seven-eighths of the value of sewage is represented by the liquid, not more than one-eighth being present in a solid form. [See Sir C. Cameron, 13035.]

> "Did you come to any general conclusion as to the proportions of liquid and solid polluting matter?—Yes; we went very thoroughly into that matter and found, somewhat to our surprise, that what appears to be most offensive to the eye in sewage was not really the chief polluting matter. What appears to the eye to be the polluting matter is the substance in suspension; but it is the organic matter in solution which chiefly contributes to the pollution of rivers. There is about one-seventh part of polluting matter in sewage in suspension, and the remaining six-sevenths are in solution; so that all remedies ought to be directed against the matter in solution rather than the matter in suspension. Moreover,

SLUDGE—*continued.*

the matters in suspension are comparatively easily got rid of by filtration and otherwise; but tho matters in solution are more difficult to remove." [Sir E. Frankland, 3000.]

It has already been pointed out that the effect of precipitants is confined in great part, if not altogether, to the deposition of the solids already present as such, the resulting liquid still containing practically the whole of its dissolved constituents. This has two important consequences; the first being that the value of the sludge is at best only a small fraction of what had been expected, and the second that its removal leaves the bulk of the polluting matter still to be dealt with. The evidence as to the first point is all but unanimous, the sludge being in many cases absolutely unsaleable, and in the others bringing merely a nominal return.

"Have you found this sludge to have any market value? —At first a small price was obtained for it, but that did not last long. For years past we have been very glad to let the farmers have it for nothing. They, however, fetch it very irregularly, and only if the carts are loaded for them. . . . Practically, sewage sludge is valueless, and very costly to handle by drying or pressing." [Colonel Harding, 7041.]

At Chorley, where the sludge is pressed, they pay 9*d.* for a one-horse load and 1*s.* for a two-horse load. [Hibbert, 7848.] Colonel Harding observed on this:—

"But you are very favourably placed, are you not, for the disposal of sludge; that is, you are a small community in the midst of a large agricultural area, and you have relatively a large number of farmers who can use it?" [7973.]

At Oldham, where also the sludge is pressed, the council "make a nominal charge of 1*s.* per ton, but we do not often enforce it. That is supposed to be the charge we make. It is giving it away, you may say." [Wilkinson, 15601.] In this case such value as the sludge possesses appears to lie, in part at least, in the lime which is added to it for the purpose of pressing.

"I have had to do with many different systems for years past, which have had the object of producing either a rich effluent or of removing the solid constituents and employing them in the form of sludge. I should be disposed to regard one and all of these, financially, as failures, and merely as items by which the cost could be somewhat reduced." [Voelcker, 10163.]

SLUDGE—*continued.*

A striking exception to the experience cited above is reported from Kingston, where the sludge produced by the Native Guano Company's process is said to have "a ready sale at 3*l.* 10*s.* per ton." [Sillar, *Interim Report*, vol. II., p. 299.]

Mr. Wollheim quotes several testimonials to the value of the pressed sludge produced by the "Amines" process at Wimbledon. [*Ib.* p. 307.]

In the foregoing the value of sludge has been considered merely from an agricultural point of view, but attempts have been made to turn it to account in other directions. Colonel Harding speaks of a process which was about to be tried at the Knostrop sewage works of the Leeds Corporation, of drying the sludge, mixing it with coal dust and oil, and selling it in the form of briquettes, adding, "we have tried the briquettes and have found them to give satisfaction." [7041, 7110-7112.]

This is not the only use which has been found for the sludge from the Leeds works. Mr. Harrison, B.Sc., Chemist to the Leeds Sewage Committee, informed the Commissioners that—

> "It was found that the flocculent residue on drying could be utilised for the removal of sulphur from crude illuminating gas. It acted as well, if not better, than the ordinary dry oxide." [5262.]

It should be added that the sewage of Leeds is peculiar in containing large quantities of ferrous sulphate and ferrous chloride, the metallic iron in which amounts on an average to no less than from four to five tons per day.

Another interesting experiment with sludge is reported from Chorley :—

> "We are at present lighting up a portion of our sewage works with gas made from our pressed sludge. The sludge is carbonised in exactly the same manner as coal, and gives off on an average 7,000 feet of 20 candle-power gas per ton. We have also made sulphate of ammonia from the ammoniacal liquor, which is slightly better both in quantity and quality than the same bye-product from coal." [Hibbert, 7761.]

See also 7839, 8038.

Looking at the evidence as a whole, however, it may fairly be said that the expectations of profit from sludge have not been fulfilled, and that this material, like the sewage before it, is generally recognised as something to be got rid of at a minimum of trouble and cost.

CHAPTER VI.

PRINCIPLES INVOLVED IN THE BACTERIAL PURIFICATION OF SEWAGE.

The agencies employed in the modern processes of sewage purification investigated by the Commissioners are, in principle, the same as those used by Dr. Poore for the treatment of excreta and slop water, and are also responsible for the purification which is effected by a sewage farm. An essential feature of these methods is the utilisation of the life processes of plants in their lowest and most minute forms. An admirably clear and interesting exposition of this branch of the subject was given by Dr. H. Marshall Ward, F.R.S., Professor of Botany at the University of Cambridge. Before going on to speak of bacteria, the witness gave a brief account of the composition of sewage:—

> "The Chairman (the Earl of Iddesleigh): What kind of mixture may sewage be regarded as?—I should regard it as a mixture containing a large quantity of water holding in solution certain organic bodies obtained both from animals and from plants; containing certain quantities of salts and of animal excreta like urea, and especially vegetable remains like cellulose and certain solid débris of animals and plants; and mixed with these, of course, products of their decomposition, in various stages of simplification, as they are breaking down to simpler and simpler things. Then there would be contained larger or smaller quantities of gases (also partly products of their decomposition), such as carbon dioxide and ammonia, and bodies of that kind; in fact, the products of decomposition of animal and vegetable nitrogenous and non-nitrogenous bodies." [Ward, 2533.]

(The nature and composition of sewage are also dealt with at some length by Sir Henry Roscoe [3510], Dr. Rideal [4131], and Sir Charles Cameron [13035].)

PRINCIPLES INVOLVED IN BACTERIAL PURIFICATION—*continued.*

"And what kinds of problems are considered in the destruction of such materials?—I should say fermentation, in the broad sense of the term; fermentations of various kinds leading to the destruction of the nitrogenous bodies, and in the end to the breaking down of these bodies into quite simple, harmless constituents, like carbon dioxide, ammonia and water, and indeed some of these, ammonia especially, being eventually further altered; and then fermentations of bodies like cellulose, of which we have of late come to know something, which would be broken down into partly gaseous and partly solid constituents, carbon dioxide and water in the end; and, in fact, the breaking down by fermentative processes to such constituents as could be used later on by plants. . . . . . I should say, in general, the great problems to be considered are the great problems of fermentation, the breaking down of complex bodies under the activities of living organisms. [Ward, 2534.]

"What agency may we consider available for this?—Fungi and bacteria, in the broad sense. . . . . . And from the particular problems offered by sewage, I should say, owing to the large quantity of liquid that there is, that bacteria would be concerned more than the higher fungi. . . . . . The action of these fungi and bacteria in nature may be looked upon as that of scavengers. . . . . . It is not difficult to make a calculation which shows the great probability that in a finite time the globe would be quite uninhabitable if it were not for this scavenging action." [2535.]

"How are the destructive actions in such organisms generally displayed?—The organisms feed upon the products of the breaking down of the complex nitrogenous and other organic bodies found in their environment, and in doing this they destroy a great deal more than they want, a great deal more than is directly utilised for their present needs; so that a bacterium, for instance, may be looked upon as excreting something which attacks, and begins to break down a mass of organic material, as then taking up some of this into its own substance to build up, and add to its own weight; and during that change it, as it were, unlocks the complex substance that it is attacking, and it falls to pieces in various ways. But the sum of it all is a

Principles involved in Bacterial Purification—*continued.*

process of change brought about only by a living body, and that is in the broadest sense what is called fermentation.

Putrefaction.

"If, however, at the same time there are produced evil-smelling gases, then fermentation is often called putrefaction, and the attempt has been made to separate artificially putrefaction from fermentation, and to restrict putrefaction to the breaking down of these complex nitrogenous animal and vegetable bodies; and also to try and distinguish between putrefaction which gives off no evil odours, as decay, and putrefaction which does give off evil odours. But an examination of the whole subject (and it is easy to give references to the best modern authorities) shows that no such lines can be drawn. Putrefaction is merely a particular case of fermentation, and the most comprehensive definition of fermentation is, 'changes produced in various bodies by the action of living organisms.'" [2538.]

"Then, in fact, you would say putrefaction and fermentation are similar processes?—Are similar processes." [2539.]

Bacteria Aërobic and Anaërobic.

"And are these processes influenced by difference in aëration and temperature and other conditions?—Yes. Many bacteria are aërobic and many others are anaërobic, and in those cases the access or otherwise of air is of the utmost importance. [2541.]

"Can you tell us exactly what you mean by aërobic and anaërobic forms?—Most known organisms, fungi and bacteria included, must have oxygen, must have air for respiration, just as an animal must. They cannot live unless they have a partial pressure of oxygen, which is comparable to that in this atmosphere at present. But Pasteur discovered, in 1861, that certain fermentations were brought about by organisms living in the depths of liquids where it was impossible that there could be any oxygen, and on working the matter out—and it has now been abundantly confirmed—Pasteur showed that these organisms not only can ferment in the absence of air, not only can live without oxygen, but that they cannot do their work in the

Bacteria Aërobic and Anaërobic—*continued.*

presence of oxygen. Oxygen acts to them like some other gas, which we are accustomed to call a poison, does to ordinary aërobic bacteria. So that at one extreme we have organisms which do their work in the absence of air, and, at the other, organisms which do their work with the full access of air, and between there are forms which require that the oxygen shall be at a certain partial pressure . . . . . And so we have these cases of aërobic and anaërobic, and partially aërobic organisms. But in addition to these there is an extraordinary physiological class of bacteria, still a small one, but very well known in some cases, which are what we now call facultative anaërobes. That is to say, if you grow them in one supply of food material, they will do without oxygen, and will carry on their fermentation in the absence of oxygen; if you then grow them on another kind of material—say nitrogenous material, whereas the last one was a material containing sugar—you must give them some oxygen; so that they can be either anaërobic or aërobic, according to circumstances, and they are therefore called 'facultative anaërobic.'" [2542.]

Professor Ward's statement in Answer 2538, as to the relation between putrefaction and fermentation, was referred to by Colonel Harding, by whom the examination of the witness was continued:—

"Then are we to understand that there are fermentations of two kinds, putrefactive and aërobic?—No; putrefactive fermentation is not necessarily aërobic. Many of the putrefactions, indeed, are anaërobic." [Ward, 2549.]

"Yes. I was rather assuming that; but are we to understand that there are these two kinds of fermentation, putrefactive or anaërobic, and aërobic?—Well, the attempt has been made to draw that distinction, but my opinion is that it cannot be held, and you will find that opinion expressed by most recent writers, such as Migula and Lafar, and other authorities; they say that it breaks down. The attempt was made to uphold putrefaction as a particular process in which evil-smelling gases came off, and which was brought about by the action of anaërobic organisms; but neither of these characteristics is true. I mean, you may have anaërobic fermentation going on without putrefactive gases and aërobic fermentations with them." [2550.]

Bacteria Aërobic and Anaërobic—*continued.*

The mode of action of the two classes of organisms was described with some fulness by Dr. Sims Woodhead, then Director of the Research Laboratories of the Royal College of Physicians and the Royal College of Surgeons:—

> "Speaking generally, how do the anaërobic organisms act?—They appear to do a great deal of work by the use of a small amount of energy, because they break up, they wrench apart, the more highly-organized products of life, and so produce unstable substances that are readily attacked, especially by oxygen. They stir things up as it were, effect a revolution, and then, while the resulting materials are in an unstable or nascent condition, they can be readily acted upon by oxygen. I think that that is the part that they play in these anaërobic beds. One or two molecules of oxygen or hydrogen, nitrogen, or carbon, are snatched from a large and complex molecular group, and this group is left in a very unstable condition, or in the form of a number of rearranged and profoundly altered molecules, many of which readily undergo oxidation. There are certain organisms, especially those which attack cellulose, that appear to act almost entirely in the absence of free oxygen." [2800.]

Further information concerning the nature and functions of bacteria will be found in the evidence of Sir Henry Roscoe [3510], Dr. Rideal [4133], Dr. P. F. Frankland [9927], and Appendix I. to that of Dr. Lorrain Smith, following Answer 13674.

A list of the principal sewage bacteria is contributed by Dr. Rideal [4133].

Bacteria occurring in Sewage.

L=liquefying gelatine. SL=slightly liquefying.
NL=not liquefying.

Obligatory anaërobes:—

Spirillum rugula, L (very active; spore-bearing; gives rise to fæcal odour).
Sp. amyliferum (in absence of air acts as a vigorous ferment).
Bacillus enteriditis sporogenes (Klein).
B. amylobacter, L (Clostridium butyricum).
B. butyricus (Botkin), L (gives much gas).
(B. subtilis is aërobic and rapidly consumes oxygen, so is dormant in the first stage.)

Facultative anaërobes or aërobes :—

B. putrificus coli, NL (decomposes albuminous substances with liberation of ammonia, whether air is present or not).

Spirillum plicatile, serpens, undula, tenue, and volutans.

Vibrio saprophilus, aureus, flavus, flavescens, NL (in sewer mud). (Weibel.)

B. Mycoides, L; Proteus vulgaris, L } produce NH_3 from nitrogenous organic matter, and denitrify.

B. fluorescens putridus (similar, produces trimethylamine).

B. fluorescens liquefaciens, L, and non-liquefaciens, NL.

Micrococcus ureæ, NL; B. ureæ, NL (convert urea into ammonium carbonate, the latter the most energetically). Flügge has also described a M. ureæ liquefaciens.

B. mesentericus, L (several varieties in London crude sewage).

Proteus mirabilis and Zenkeri, L.

B. megaterium, L; liquefaciens, L; magnus, spinosus.

Streptococcus liquefaciens coli, L, and mirabilis, NL.

B. saprogenes I., II., III.; pyogenes and coprogenes fetidus.

B. acidi paralactici.

B. lactis aerogenes, NL (produces CO_2 and H).

B. coli communis, NL (produces much gas, mainly H).

Cladothrix dichotoma, L.

Proteus sulphureus, L (produces H_2S and mercaptan).

Bacterium sulphureum, L (liquefies gelatine and casein, produces H_2S). (Found by Sims Woodhead in Exeter sewage.)

Beggiatoa alba (secretes granules of sulphur, formed, according to Winogradsky, by oxidation of H_2S, and finally turned into sulphuric acid by the plant).

The following forms reduce nitrates to nitrites :—

B. vermicularis, liquidus, ramosus, aquatilis (grows luxuriantly in ammonia solutions); besides mycoides and Proteus vulgaris.

The following were found by Jordan in the sewage of St. Lawrence (*sic*), Massachusetts :—

B. cloacæ, L, ubiquitus, NL, reticularis, SL, circulans, L, hyalinus, L, all reducing nitrates; superficialis, SL, not reducing.

Those who are interested in the appearance and habits of the sewage bacteria, and the methods which are relied on for their identification, will find full information on these points in Dr. Houston's second and third reports to the London County Council on the bacterial treatment of crude sewage. The chemical changes which they bring about, and the products resulting from the decomposition of the various typical constituents of sewage, are described in considerable detail by Dr. Rideal in his work on "Sewage and its Purification."

Enzymes.

It should be borne in mind that although, as a matter of convenience, it is customary to speak of the natural purification of sewage as "bacterial," yet bacteria properly so called are not the only forms of life which are concerned in this work, a part of which, moreover, is effected not by living organisms themselves, but by certain products which they throw off. These are referred to incidentally by Dr. Rideal in his evidence, and the short description of them which follows is taken from his book above referred to (pp. 77, 78):—

"A great number of changes, most of them hydrolytic, are accomplished by the large class of organic substances termed 'enzymes,' which, though not living, are products of animal and vegetable life. These enzymes have been defined by Lehmann and Neumann as 'chemical bodies, which in minimum amounts, and without being used up, are able to separate large amounts of complicated organic molecules into simpler, smaller, more soluble and diffusible molecules.' The definition is not quite accurate, as the milk ferment, for instance, actually coagulates casein, or renders it insoluble; but it gives an idea of the immense power that these enzymes possess, and the economy of their use as distinguished from ordinary chemical or mechanical means. Their importance to us is shown by the fact that a large number of them are the products of bacteria or other fungi, and are powerful agents in their resolving action. By their means a bacillus is not only able to act in its immediate neighbourhood, but also at a considerable distance, through the soluble ferments it forms and disengages.

"The enzymes are soluble nitrogenous bodies, which can be precipitated and rendered inert by strong alcohol, mercuric chloride, and by boiling. They can be separated from bacteria by filtration, when the soluble enzymes pass through, while the bacteria are retained. Other distinctions from the organisms which produce them are:—

"1. Enzymes can work at a greater range of temperature—that is, are less susceptible to heat and cold—than the living bacteria. Therefore it is possible to find temperatures which will inhibit, if not kill, bacteria, without affecting enzymes.

"2. Antiseptics, like chloroform, thymol, &c., which kill or inhibit bacteria, do not prevent enzymes from acting.

ENZYMES—*continued.*

Thus, Salkowski inoculated fibrin with putrefactive bacteria and kept it in chloroform water. It remained sterile for an unlimited time, but nevertheless underwent solution with the usual products, due to an enzyme secreted by the bacteria at first."

See also Rideal, 4138-9-40.

This brief résumé of the life actions involved in the purification of sewage will be fitly concluded with a quotation from Sir Henry Roscoe's observations on the state of our knowledge concerning them:—

"A complete examination of the complicated questions involved in the action of the various organisms taking part in the natural purification of sewage is of paramount importance, but such an investigation, I need scarcely point out, is one not only requiring a considerable expenditure of time and labour, but involving one of the most delicate and difficult problems of modern science, as our knowledge of these actions is as yet incomplete." [3510.]

The lack of a full knowledge of the inner working of bacterial purification processes has been urged in some quarters as a ground for hesitating to adopt bacterial filters and for adhering to sewage farms. It probably did not occur to the sapient propounders of this view that our knowledge of the action which goes on in the course of purification by land is no more complete than in the case of filters. The main point is that enough is known of the conditions which are essential to effective biological action to enable us to lay out sewago farms and to construct bacterial filters with a reasonable prospect of success.

CHAPTER VII.

THE NEED FOR PRELIMINARY TREATMENT.

A question of the utmost importance is that as to the need or otherwise for a preliminary treatment of sewage. The opinions elicited by the Commissioners on this point are therefore particularly valuable.

This question, like other branches of the subject, may be dealt with both from a theoretical and from a practical point of view.

The following is the evidence of some of the witnesses who regarded it from a scientific standpoint:—

> "Could you tell us generally what part bacteria play in carrying on the work?—Well, I think they play two very important parts, perfectly distinct and occurring at entirely different stages of the process of disintegration. From all that I have seen—and I have now examined a number of those filters, six or eight—I have come to the conclusion that there are two distinct processes. Of course that is generally accepted, but it is not so generally accepted that these must be kept perfectly separate. There is an anaërobic change in which we have what corresponds to, what are usually spoken of as, putrefactive processes, and secondly we have the aërobic changes, which correspond, of course, to what is known as nitrification. . . . But wherever these two processes are too mixed up, even though the organisms can live to a certain extent side by side, it is found that the rate at which the individual process proceeds is to a certain extent interfered with. You have the series of changes, and the same ultimate results, but they do not go on so rapidly as when you can keep the two sets of organisms almost distinct. Of course they can never be kept, so far as we can see, perfectly distinct, but it is possible to obtain a high degree of anaërobic change, and a high degree of aërobic change, by controlling and modifying the conditions under which the sewage is broken down." [Woodhead, 2797.]

"You have heard that there are filters, I suppose, in

which aërobic action is relied upon alone?—Yes; but I do not think it is ever a pure aërobic change." [2829.]

"... Of course, one can imagine conditions under which the aërobic disintegration would be possible, and as an experiment one knows that a breaking down by aërobic organisms only can occur; I think it is not only possible, but probable. [2830.]

"Well, now, take broad irrigation of sewage. What takes place there, aërobic or anaërobic, or both actions?—Both, decidedly." [2831.]

"The aërobic on the surface of the soil?—The aërobic on the surface of the soil, and the anaërobic deeper down in the soil." [2833.]

"Now, do you attach any importance to which of these processes takes precedence, the anaërobic or the aërobic?—Yes, ordinarily. [2835.]

"Where the work has to be done rapidly, and where it has to be done in a limited space, I think the anaërobic change must come first, but must be stopped at a certain stage." [2836.]

"And do you think that the whole of the first series of changes leading to ammonia is necessarily anaërobic?—Well, I hold that they are principally anaërobic." [2871.]

"Why should not the whole treatment of sewage be aërobic—aërobic as far as the change to ammonia, and aërobic as far as regards the subsequent change to nitrates?—Because most of the organisms that produce ammonia under these conditions require special substances on which to act." [2879.]

"In 1893 I recognised it as necessary, but I also found out that, at any rate in dealing with crude sewage, the first operation should be of an anaërobic character." [Scott Moncrieff, 3176.]

"I believe, as a general principle, it is better to do the work by the aërobic rather than the anaërobic." [Dibdin, 3857.]

"And the difference between your two beds is simply a difference of passages?—Purely. I do not believe there is any difference in the actual action which takes place at all; I believe it is merely that you must make it coarse, because you have to deal with coarse particles." [3874.]

"As sewage contains little or no oxygen, nearly all these

NEED FOR PRELIMINARY TREATMENT—*continued.*

species must be at least facultatively anaërobic, and the decompositions they engender are hydrolytic; consequently it is a mistake in the first stages to introduce air, which merely hinders the anaërobic changes, and at this point only weakly encourages the aërobic ones. [Rideal, 4133.]

"What is the advantage of the first or anaërobic stage?—I have always been of opinion, and have often urged on previous occasions, that the anaërobic change is an integral part of the preparation, and that the neglect and even avoidance of it has been a frequent cause of failure. As Rudolph Hering aptly remarks: 'The aërobic process, when applied to organic matter in suspension, is slower than the anaërobic process. It takes a long time for solid particles of organic matter to disappear as such, when the conversion depends on the oxygen contained in the water. It takes a short time when it is brought about by anaërobes, which produce conditions causing liquefaction. The reverse seems true in the case of organic matter in solution, because the aërobic bacteria, and conditions favouring a thorough aëration of liquid sewage, will remove a much greater amount of organic matter from the water in the same time than if it is left to the action of anaërobes.' Therefore the processes should be properly and systematically conducted in natural sequence. Any mixing or confusing in the order, any artificial interference, or attempt to work distinct reactions simultaneously in the same receptacle, will lead to uncertainty and irregularity in the results." [4134.]

"I believe that the anaërobic change is a necessary preliminary very largely from a chemical consideration that the breaking down of these organic bodies takes place without the absorption of oxygen, without any chemical addition to the substance; you have a breaking down of the organic matter by the organism to ammonia and to marsh gas or to carbonic acid, but that oxygen for the carbonic acid is not derived from atmospheric oxygen but from hydrolysis; the changes are hydrolytic changes, and therefore they are brought about by organisms which are acting anaërobically; even if they are aërobes the oxygen is not concerned in the change. In the same way as yeast, although yeast is an aërobe, it does its work best *in vacuo* or in the absence of air at the bottom of the vat." [4287.]

"Do you think that the antecedent anaërobic action of the septic tank facilitates subsequent filtration apart from the reduction in amount and the fine division of the suspended solids?—No; I am disposed to think that the filtration is only assisted in regard to suspended solids." [Harding, 7262.]

"During the earlier period our septic tank effluent did not come thoroughly into condition. That is one of the results which leads me strongly to the opinion that you require to have a thoroughly septicised effluent to get very good nitrification." [Fowler, 8548.]

"In nature both aërobic and anaërobic bacteria are found in close juxtaposition, and the chemical changes which they are respectively capable of bringing about go on side by side, the one or the other predominating according to circumstances. In order to improve upon nature these forms and the processes dependent on them should be separated as far as possible.

"As far as our present information goes the purification of sewage cannot be completed by means of anaërobic bacteria alone, and it is necessary, therefore, that in the final stages of the purification aërobic conditions should exclusively prevail. . . . . [Dr. Frankland, vol. II., *Interim Report*, p. 530.] See also 2812, 2813, 2927, 2930, 3538, 4288 *et seq.*, 4416, 9951.

It will be seen that most of the witnesses lay strong emphasis upon the need for dividing the work of purification into two stages. We have now to consider how far their conclusions are borne out by practical experience.

The Need for Preliminary Treatment in connection with Land.

Where the purification is to be completed by land the need for preliminary treatment seems to be fairly well established.

The Royal Commission on Metropolitan Sewage Disposal, in their final Report, express the opinion

"That it appears desirable, when the area of land is considerably reduced, that the sewage should be previously treated by some efficient process for removing the sludge." [Adrian, 75.]

"It is desirable that where land treatment is followed,

PRELIMINARY TREATMENT BEFORE LAND—*continued.*

the solid matters in the sewage should not be passed on to the land with the liquid, otherwise it is found that such matter decomposing on the surface is destructive to the crop, and is liable to be a nuisance, especially at certain seasons of the year." [Latham, 4505.]

"Then where nuisance arises—and, of course, nuisance does arise sometimes in connection with these farms—is that nuisance due, do you think, to the decomposition of the solids coming down with the sewage rather than from the impurities in solution?—I think it is entirely due to the decomposing solids upon the surface of the ground. [Dr. Wilson, 6303.]

"Are there cases where you think it is advisable, in the first instance, to settle the solids before the sewage is passed upon the land?—It seems to me generally advisable, unless there is a very large area of land available, to take out the bulk of the rougher suspended solids before passing it on to the land." [6304.]

"I think that if you deposit the solids, either by mechanical means—that is, by simple subsidence, mechanical subsidence in a considerably-sized tank—I think that makes a very great deal of difference, and renders the application of the sewage to the land far more suitable. [Chatterton, 6434.]

"Far more suitable?—Far more suitable; and I would go so far as this—that I think it ought to be done in every case." [6435.]

"When sewage is going over the land, do you advise that there should be some kind of preliminary treatment, or would you let the raw sewage go on the land?—If you have preliminary treatment—if you remove the solid matter, you do not require so large an area of land. In that way it is advantageous; and also if you run raw sewage on to land it may possibly cause a nuisance. In hot summer weather it is more likely to cause a nuisance if the solid matter flows on to the land, and has to be treated on the surface, than if it has previously been settled in tanks." [Tatton, 6589.]

"When sewage containing any considerable amount of trade waste is treated on land, I should consider it advisable that there should be preliminary treatment in precipitation tanks." [6627.]

"May I ask you next whether you consider it desirable that before the sewage is put on to the land it should go through any preliminary treatmont?—I have always been of that opinion, my Lord. Crude sewage—absolutely crude sewage—should not be put on land; it should receive treatment, either mechanical, chemical or bacterial, prior to application . . . . to get rid of the solids." [Balfour, 6843, 6844.]

"As regards land treatment, do you consider that there ought to be some preliminary treatment of sewage before it is turned over land?—Yes, I think it is well to take out the grosser solids; I think that is very helpful." [Strachan, 7617.]

"What we find is this: that with the detritus tank and the first contact bed for clarification, we can treat from two to three times, I should say quite three times, as much sewage on the land as you can without this system of clarification. That is the result of our experiments." [Mawbey, 8264.]

"Then you come to a larger class when you deal with the question of towns. . . . . Leaving out, for the moment, the complication of it with manufacturing refuse, you have a very large volume, a very much larger volume to deal with than you have in rural districts. Therefore, I think you must adopt some system of settlement, and remove the solid matters before you turn tho sewage on to the land, or, as an alternative, you must adopt some system of precipitation." [Voelcker, 10164.]

See also 3538, 3548, 3549, 7661, 10179, and pp. 306, 307.

THE NEED FOR PRELIMINARY TREATMENT BEFORE FILTRATION.

The late Colonel Ducat was strongly of opinion that the solid as well as the liquid impurities of the sewage could be dealt with in his filter:—

"What becomes of all those (grosser solids) in their passage through your filter; are they broken down?—I presume they are; I have never seen them again. Of course, the proportion of them would be very small. I do not say they would not be there in time; if we were working for many years, they could not go very far down. [Ducat, 2241.]

"The smallor solids in suspension, which go to form ordinary sludge, do not come out of the filter?—No, they are entirely disposed of." [2242.]

Preliminary Treatment before Filtration—*continued.*

This experience was not borne out at Leeds:—

> "We used the crude sewage for the first few months, but found that the sewage matters merely clogged the surface of the bed, and after a while prevented the aëration of the filter, and we got bad effluents with regard to putrescibility. We had to clean the surface of the filter about once every six weeks, and then we should get good effluents for a period, and after trying this for several periods we then commenced, a year last May, to turn the septic tank effluent on. Since then we have turned the septic tank effluent on without stopping in any way." [Harrison, 15053.]

With the exception of Colonel Ducat, the witnesses were practically unanimous as to the need for a preliminary treatment of some kind before filtration.

A distinction is drawn, in some cases, between screening out the larger solids and a more thorough treatment for the removal of the fine suspended matter and the hydrolysis of the liquid.

The Necessity for Screening.

The necessity for screening, in the absence of cultivation tanks or septic tanks, is generally conceded, but with either of these it is recognised as superfluous:—

> "In the case of broad irrigation, either on ordinary land or a specially prepared plot of land, called for convenience a 'bacteria bed,' the sewage should pass through a screen or screens to remove rags, &c. The quantity of matter so obtained from the Sutton works is only twelve barrow loads per day, equal to thirty barrow loads per million gallons of sewage." [Dibdin, 2170.]
>
> "The sewage before being run on to the filter must be subjected to the ordinary screening usually adopted at sewage disposal works, and for this screens will have to be provided; and where there is much road detritus to be dealt with, it will be well to construct suitable silt traps, which are simple and not costly." [Ducat, 2186.]
>
> "A large screen I regard as essential, whatever system is adopted." [Strachan, 7521.]

"Upward screening," of which Mr. Strachan speaks very highly, is noticed elsewhere (p. 84) in connection with the Scott Moncrieff "cultivation tank."

The nature of the matters intercepted by the screens at Leeds is described by Colonel Harding :—

> "The sewage used was the crude sewage after passage through three screens, the smallest of which was thirty-seven per inch. The first of these screens, which had one-eighth inch mesh, kept back small pieces of paper, matches, &c., and the second and third screens kept back most of the fibre, but all the finely-divided solids in suspension passed on to the beds. The keeping back of matter by the screens, although it greatly facilitated the work, did not remove any important proportion of the solids in suspension, the matters removed being those which usually do not come into the analysis, as paper, matches, fibre, &c." [Harding, 7374.]

It will be noted that even the very fine screens used in this case did not make any great impression on the solids in suspension.

Mr. Chatterton states that he "is not a great believer in screens" [6437], and Dr. Rideal described some specific objections to their use :—

> "The smaller remains of vegetable matter which pass down sinks occasion considerable nuisance when an attempt is made to remove them by screens or on the top of a coarse filter. They act objectionably in three ways :—
>
> "1. They set up acid fermentation and corrode iron ;
>
> "2. Many of them, like the cabbage family, contain sulphur compounds and evolve very offensive odours ;
>
> "3. They form a pulp which blocks the strainers ;
>
> "Under anaërobic conditions in a closed space they rapidly rot away and disappear, their pectose first dissolving and then their cellulose, while the ammonia takes up the acids." [4145.]

In Answer No. 6501 Mr. Chatterton refers to screens as desirable in connection with a sea outfall, and speaks of the difficulty which is experienced in acquiring a small piece of land on which to lay them down.

The Need for more thorough Preliminary Treatment.

The following is the principal evidence given in favour of a more thorough preliminary treatment :—

> "And probably you think it would be better to have some preliminary precipitation ?—I certainly hold that view

NEED FOR MORE THOROUGH PRELIMINARY TREATMENT—*contd.*

at present. Of course, as I have told you, I have had something like twenty years' experience of filters, and I see nothing to convert me to the view that it is best to run the sewage straight from the sewer on to the surface of the filter under all conditions." [Crimp, 1673.]

"Then if you find both kinds (of bacteria) in the filter, is it not possible that filtration alone is sufficient to purify ordinary sewage without being previously treated either in a precipitation tank or in a septic chamber?—I certainly think that no precipitation is necessary, but I think there is a distinct advantage in having first a septic chamber, or an anaërobic chamber, whichever form it takes. There is a distinct advantage in having that as a preliminary breaking-up of the sewage, as it were." [Woodhead, 2930.]

"I have not had sufficient evidence put before me to enable me to state whether it is possible to put crude sewage containing solid matters on to an artificial filter with success." [Roscoe, 3546.]

"For any system of sewage treatment to be perfect you must have as nearly as possible a perfectly average sample to deal with. You do not want to have to deal during one hour of the day with sewage at 2, and in the next hour of the day sewage at 0·2 albuminoid ammonia." [Whittaker, 4953.]

"Why not?—Because no filter can deal with it." [4954.]

"I am quite clear upon this, that it is not profitable to throw any material amount of solid matter upon any kind of filter. Solid matter occurring in crude sewage is far more easily and economically dealt with in some sort of tank." [Stoddart, 5019.]

"My opinion now, after the experience I have had with them, is that the action of the septic tank is to enable the tank effluent to be dealt with by an aërated filter, and that it is only the change in the character of the tank effluent that permits of its purification by means of an aërated filter." [Whittaker, 5752.]

"Anyway, contact beds seem to me much more likely to succeed if they are used to purify thoroughly settled sewage or septic tank effluent; and it is an important advantage of the septic tank that it equalises the conditions of the sewage, whereas if more or less crude sewage is put on the beds the

NEED FOR MORE THOROUGH PRELIMINARY TREATMENT—*continued.*

conditions are constantly varying, especially if there is any large admixture of trade effluents." [Harding, 7069.]

"We concluded that this system of treatment (dealing with crude sewage) would be impracticable for Leeds; that it would be better to reduce the area of the filters by introducing some preliminary treatment with the view to reduce the amount of suspended solids to be dealt with on those filter beds." [7206.]

"(Mr. Frye): And the chemist told me that he would not advise a scheme at all where the sewage was not subjected to preliminary treatment." [7211.]

"In connection with trickling filtration, without previous septic tank treatment, there would, I fear, be a difficulty, especially in small installations; because when sewage travels only a short distance before reaching the works, paper and fæces arrive in a somewhat unbroken condition, and possibly with domestic sewage the septic tank may be necessary in most cases, in order that suspended solids may reach the trickling filters in a finely divided condition." [7400.]

"Do you consider that that preliminary treatment is desirable?—Well, I do not say that it is essential. I think it aids the contact beds, or the continuous filters, very much, and in my own practice I put it in when I get the chance. I do not bind myself that it is essential; I think it is useful and advisable to have." [Strachan, 7518.]

"I should like to ask you if you have seen reason to change the opinion that you then expressed: that it is impracticable to deal on contact beds with sewage which still contains the great bulk of its suspended solids, and it is therefore necessary to first remove from the sewage the bulk of its solids either by chemical precipitation, or by natural subsidence, or by septic tank action; is that still your opinion?—That is certainly my opinion." [Fowler, 8362.]

"Many of the failures which have taken place in connection with the use of bacteria beds are doubtless due either to the entire absence of septic preparation, or to the application of unduly large quantities of sewage to the beds, also to faulty construction of the beds." [Dr. Frankland, 9927.]

NEED FOR MORE THOROUGH PRELIMINARY TREATMENT—*continued.*

"Do you consider that crude sewage should be treated on contact beds without previous sedimentation?—It seems to me highly undesirable that it should be done, because it must lead to the blocking up of the beds." [10089.]

"(General Carey): You claim to purify the sewage of a quarter of a million of people on $5\frac{1}{2}$ acres of beds, after precipitation in tanks. It is a remarkable result, but you attribute it principally to efficient precipitation in the tanks? —The efficient precipitation is a first essential. That gets rid of about half of the pollution, according to the analysis. Then the protection of the bacteria beds by the roughing filters, I think, is very important, as it prevents that silting of the surface which sometimes occurs." [Corbett, 15466.]

See also 1593, 2014 *et seq.*, 3538, 5754, 5755, 7382, 7413, 7460.

PRELIMINARY WORK DONE IN SEWERS.

The sewage of a large town undergoes a preliminary treatment in the sewers through which it passes.

"In a trunk sewer there is a certain amount of decomposition going on undoubtedly. [D. Cameron, 2070.]

"If the sewage of a town happened to flow to works for a mile or two . . . . then the sewage would be more nearly in the state which you aim at than if it were taken immediately the intercepting sewer began?—I conclude that less stay in a tank would be necessary under such conditions." [2071.]

"Favourable conditions should be provided by well-ventilated and self-cleansing sewers for the work of a mixed group of aërobic organisms." [Scott Moncrieff, 3194.]

"You mentioned the fact that your sewers act as septic tanks?—Septic action takes place in sewers." [Harding, 7347.]

"Therefore in forming an installation for sewage works, consideration should be had to the length of the sewers bringing the sewage to the works?—It may be taken properly into account, because, undoubtedly, septic action does take place where sewage passes through a long length of sewers." [7349.]

CHAPTER VIII.

PRELIMINARY BACTERIAL PROCESSES.

The preliminary bacterial processes differ from chemical precipitation in that, while the latter aims at throwing down the suspended matter as sludge, the object of the former is to destroy as much of this material as possible. This work is mainly accomplished by the various liquefying bacteria and their enzymes, an account of which has already been given, the difference between the various processes consisting chiefly in the manner in which they are brought into play.

The Cultivation Tank.

The first of these processes to be introduced was the "cultivation tank," invented by Mr. Scott Moncrieff in 1891. The description of the tank given in his evidence [3106 *et seq.*] can hardly be followed without the drawings, to which frequent reference is made. It consists, briefly, of a chamber filled with large stones carried by a grating, into the space under which the sewage is admitted, and through which it passes slowly upwards, escaping by an overflow at the top. The object of the stones is to afford a resting-place for the anaërobic organisms by which the solids are liquefied, and the inventor attaches some importance to the zonal character of the bacterial action, that is to say, to the succession in the various layers of different conditions with regard to aëration as the oxygen dissolved in the raw sewage becomes consumed.

> ". . . . If the conditions remain constant, you have zones representing different stages of decomposition, each having organisms best capable of carrying on the work." [Scott Moncrieff, 3114.]

With regard to the material used, Mr. Scott Moncrieff says:—

> "I tried various materials, but flints were the best." [3117.]

The cultivation tank is referred to by Dr. Sims Woodhead [2796 *et seq.*] and Dr. Rideal [4139, 4292, 4460], and the chief results which it yields are set forth by the latter in "Sewage and its Purification" (p. 209), as follows:—

"Mr. Scott Moncrieff found that the liquefaction of the

solids was so effective that the whole sludge of seven years from a household of ten persons was absorbed on nine square yards of land, causing no distinction in appearance between this soil and that surrounding. The space beneath the under-grating of the tank had a capacity of less than five cubic feet, and would obviously have filled up in a short time but for the liquefying action that had taken place."

Mr. Strachan speaks in high terms of "upward screening," apparently referring to some form of "cultivation tank." He remarks :—

"It seems to me the stuff comes out a great deal cleaner than mere mechanical straining, and the small quantity of sludge relatively that you get left is very striking." [7664.]

The Septic Tank.

Next in point of date comes the septic tank invented by Mr. Cameron, the object of which he mentions in his evidence as follows:—

"The aim I had in view was to bring the sewage into such a condition by arresting the solids in suspension as to make the filtration on artificial filters practicable; at the same time taking advantage of the solvent action that goes on in the arrested solids, so as to make the quantity of deposit or sludge as small as possible." [1862.]

His description of the tank itself is interspersed with a large amount of statistical and incidental matter which it is unnecessary to reproduce here. It will suffice to state that the septic tank consists essentially of a chamber through which the sewage is allowed to flow continuously, the inlets and outlets being preferably submerged, so as to prevent the disturbance of the scum which forms on the surface. It differs from Mr. Scott Moncrieff's "cultivation tank" in that no material is placed in it to furnish surfaces for the liquefying microbes to cling to, but resembles it in that the conditions maintained in both are anaërobic.

The septic tank has received a large share of the attention of the Commissioners, and forms a part of four out of the ten combinations of artificial works enumerated in their interim report. [*Interim Report*, p. ix.]

Destruction of Sewage Solids in Septic Tank.

The efficiency of the septic tank as an instrument for the liquefaction of sewage solids was testified to by every one of the large number of witnesses who were examined on the subject, with the single exception of Mr. C. J. Whittaker, Chairman of the Accrington and Church Outfall Sewage Board. [Whittaker, 5745 to 5753.] The favourable evidence on this point may be found in answers 833, 2819, 2946 *et seq.*, 3696, 5479, 5544, 6442, 7195, 7247, 7254, 7265, 8370, 14507 *et seq.*, 14528, 14552, 14817.

Some difference was manifested in the experience of different witnesses as to the proportion of the solid matter so destroyed. At Exeter, after thirteen months' working, Mr. Cameron found that 81 per cent. of the solids which had entered the tank had disappeared. [Journal of Sanitary Institute, XVIII., p. 565. See also Royal Commission Report, answers 1879, 1880.]

At Accrington, Mr. Whittaker tells the Commissioners he

> "worked from the beginning of February to the beginning of July, and there was not as much sludge in appearance or in quantity as there would have been in one week's chemical precipitation." [4811.]

This statement is withdrawn in Mr. Whittaker's later evidence above referred to.

At Manchester, in July, Mr. Fowler estimated, "taking one thing with another . . . . that from a-half to two-thirds [of the solids] had disappeared." [5544.]

In March, 1901, as the result of further experience, he mentioned 26 per cent. as the average amount of digestion; but it should be noted that this was in tanks holding only one-half of the daily flow. [8373.]

At Leeds, in the No. 1 tank, holding twenty-four hours' flow, Colonel Harding estimates that

> "there was a digestion of 57 per cent. of the solids left in the tank, which is equivalent to about 40 per cent. of those originally in the sewage." [Harding, 7254.]

For No. 3 tank, the corresponding figures were 60 per cent. and 28·7 per cent., and for the closed tanks, 40 per cent. and 27 per cent. He adds:—

> "It is probable that the proportion would be somewhat larger with simple domestic sewage. It is necessary to add that if the exit of suspended solids in the effluent—which

Destruction of Sewage Solids in Septic Tank—*continued.*

takes away 20 to 30 per cent. of them—could be prevented, the digestion would be larger, for the figures show a digestion of 50 per cent. of the solids left in the tank." [7255.]

At Leicester, Mr. Mawbey estimates the reduction of solids in the closed detritus and septic tanks at 83 per cent., and in the open subsidence tank at 84 per cent. [8297.]

At Birmingham, Mr. J. D. Watson tells us that practically the whole of the sludge which is deposited in the septic tanks is dissolved. [14528.] He mentions a case in which the conversion of a sewer, eight feet in diameter, into a septic tank resulted in the destruction of sludge which it already contained. [14554.]

At Sheffield, Mr. Haworth estimates the consumption of sludge at a maximum of 31·9 per cent. [14817.]

A great deal of information as to the results obtained in the bacterial treatment of sewage has been collected by Professor Frank Clowes, D.Sc., F.I.C., Chief Chemist to the L.C.C., and tabulated in convenient form for reference in his fourth report. The following table, showing the amount of solid matter destroyed in various septic tanks, is condensed from those of Dr. Clowes:—

Birmingham (Open tanks)—"The sludge which had to be disposed of before septic tanks were used amounted to double that which has now to be removed from the sedimentation tanks." (This relates to the sedimentation tanks, which are emptied at short intervals; the septic tanks are referred to above.)

Blackburn (Open tanks)—The reduction effected amounts to 72 per cent. of the suspended solid matter.

Glasgow	(Open tank)—	Sludge	reduced by	54·25	per cent.
Huddersfield	,,	,,	,,	38	,,
Leeds	,,	,,	,,	28	,,
,,	,,	,,	,,	18	,,
,,	,,	,,	,,	28	,,
Manchester	,,	,,	,,	75·70	,,
,,	,,	,,	,,	21·6	,,
,,	,,	,,	,,	33·5	,,
			Est.	50·0	,,
Rochdale	,,	Total solids	,,	26·5	,,
		Suspended solids		62·0	per cent.
Wolverhampton	,,	Sludge	,,	33	per cent.

It has often been stated, on the authority of some of the foregoing results, that the septic tank destroys so much per cent. of the solids, or that it cannot liquefy more than so much.

It is hardly necessary to point out that general statements of this kind cannot safely be made on the strength of a single set of experiments. In the first place, the proportion of solids destroyed is largely dependent on the composition of the sewage and the presence or absence of solids from manufacturing processes, and of road washings. The effect of the latter on the proportion of solids destroyed would vary with the paving material, macadamised or asphalt roads yielding much insoluble matter, while the fibrous débris from roads paved with wood would be susceptible of a certain amount of change. Another point of the utmost importance which is often lost sight of is the length of time during which the tank has been in operation, and the period elapsing between its being thrown out of work and the measurement of the solids therein. It is obvious that a tank which is capable of digesting, say, 80 per cent. of the solids might be emptied at a time when only 60 per cent., 40 per cent., or even 20 per cent. had been destroyed, and that in any case in which the amount of solid matter is measured while a tank is in work, or immediately afterwards, there will be a large amount of such matter present which has been exposed for a very short time to bacterial action.

Percentage of Moisture in Tank Residuum.

The amount of solid matter liquefied does not for practical purposes afford a full measure of the efficiency of a tank in this respect, to arrive at which the bulk of the residuum, as well as its weight, should be taken into account. In a paper read by the writer in 1901, at the Eastbourne Congress of the Royal Institute of Public Health, he gives the percentage composition of the deposit in the septic tank at Exeter already referred to.

A sample taken from the top of the deposit contained 88·8 per cent. of moisture, and one from mid-depth 83·9 per cent., while the proportion of moisture in the deposit from the bottom of the tank was only 80 per cent. Comparing this last with the 90 per cent. of moisture in ordinary sewage sludge, it will be seen that the difference would reduce the bulk of the deposit by one-half, even if no liquefaction whatever had taken place.

The percentage of moisture in the residuum from a large number of septic tanks in various parts of the country is given as follows by Dr. Clowes in his table already referred to:—

Accrington, 76·7; Blackburn, 90; Glasgow, 92; Haslingden, Rawtenstall and Bacup, 90; Huddersfield, 91·3; Leeds, 82, 80,

PERCENTAGE OF MOISTURE IN TANK RESIDUUM—*continued.*

82; Leicester (tank used only 18 weeks), 90·77; Manchester, 85; Rochdale, 89·8; York, 89·3.

A point which to local authorities will be of even greater importance than the absolute quantity of residuum remaining to be disposed of is the frequency or otherwise of the occasions on which this matter must be removed. With certain kinds of sewage, or with tanks of inadequate capacity, this may have to be done at comparatively short intervals, say every twelve months. On the other hand, the septic tank at Belleisle, Exeter, was in use for five years before it became necessary to cleanse it.

At Birmingham, Mr. Watson called the attention of the Commissioners to some tanks which had been in operation for three and a-half years without cleaning out, and expressed the opinion that no necessity for doing so would arise in the near future. [14506, 14527.]

It should be noticed, however, that the sewage, before reaching these tanks, passes through receiving tanks or large grit chambers, which are regularly emptied. [14493 *et seq.*]

At Barrhead, N.B., four septic tanks, serving 10,000 people, have been at work for six years without interruption or interference of any kind. They have never been cleaned out, and, so far as people on the spot can judge, may never require to be.

CHARACTER OF TANK RESIDUUM.

Some interesting evidence was obtained as to the nature of the solid residuum which results from the destruction of sewage solids in a septic tank.

Mr. Cameron handed in a report by Dr. Rideal giving the percentage composition of the deposit in the Exeter tank:—

"*Examination of the deposit in tank at different depths.*

Percentage composition of deposit dried at 100° C.

——	3 inches from bottom.	9 inches from bottom.	15 inches from bottom.
Mineral matter	67·65	67·60	68·69
Organic matter	32·35	32·40	31·31
Nitrogen	2·38	2·34	2·45
Nitrogen in organic matter..	7·36	7·22	7·82

CHARACTER OF TANK RESIDUUM—*continued.*

"From a microscopic examination of the above three deposits, I find that they consist of a black amorphous matter, with vegetable and animal débris much altered and comminuted. No marked difference in the several depths was noticed except that in the lowest deposit there were great numbers of large amœbæ, whilst in the upper one anguillulæ were prevalent, which may indicate somewhat different action in the different layers." [1909.]

The deposit in the Acerington tanks appears to consist of

"black gelatinous matter that you could scarcely call sludge, that you could not press." [Whittaker, 4793.]

On the second occasion of his appearance before the Commissioners, Mr. Whittaker compares the deposit in the septic tanks with the sludge from chemical precipitation as follows:—

"It is of a very much handier kind, more easily dried, and easier to deal with." [5757.]

On the other hand, Mr. Tatton says of the deposit from septic tanks:—

"It is more objectionable, no doubt, as regards smell from it. It was very objectionable at Manchester." [6730.]

An explanation of this is afforded by Mr. Fowler's evidence [5545], to the effect that only about one-half the organic matter in the sludge had disappeared, from which it follows that the mineralisation of the deposit was much less complete here than at Exeter. Mr. Fowler himself qualifies his evidence on this point with the significant words, "working at the rates at which we have been working."

Colonel Harding, on being asked "Was the sludge from the septic tanks very offensive?" replied:—

"We expected it would be, but at Leeds we were not inconvenienced," [7253.]

and in a subsequent answer gave the following particulars of its composition:—

"We made many analyses. Roughly speaking, they showed that the dried sludge of our open septic tanks lost on ignition about 50 per cent., leaving ash about 50 per cent., about one-third of which was ferric oxide and about half silica. Therefore about one-half of the dried sludge was in a form not further reducible by bacterial action." [7256.]

Here, again, it is evident that the mineralisation of the residuum was far from complete at the time of its withdrawal.

Character of Tank Residuum—*continued.*

Concerning the behaviour of tho deposit, Colonel Harding remarked :—

> "Mr. Harrison reminds me it would be easier to deal with septic tank sludge because it dries more rapidly; it settles and dries more rapidly than the other sludge; it is more largely mineral." [7288.]

The deposit from the septic tanks at Burnley was pressed with lime and sold to the surrounding farmers for 10*d.* per ton, "that is, the lime value. There is no other value in it." [15356.]

The Borough Surveyor, Mr. G. H. Pickles, Assoc. M.Inst. C.E., in reply to a question as to the offensiveness of the solid matter from these tanks at Burnley, said :—

> "I do not think it is specially offensive, but it is more difficult to press." [15361.]

On the other hand, Colonel Harding points out that while

> "the drying of septic sludge on land or lagoons will not be free from nuisance" . . . "the nuisance will be of short duration, because the putrefaction is half completed, while in the sludge from chemical settlement the putrefaction is not begun, but must eventually arise." [7261.]

The following description of the tank deposit is given in Dr. Rideal's book on sewage, pp. 81, 82 :—

> "The 'bye-product' of these re-actions is a varying but small quantity of dark, pulverulent matter resembling the humus or peaty substances of soil. It is of somewhat indefinite constitution, containing nitrogen, but is innocuous from its very stability. . . .
>
> "As compared to the voluminous 'sludge' of chemical or mechanical treatment, the anaërobic liquefaction leaves only a small quantity of this earthy matter, which requires no special provision."

See also 5545, 5745, 5912.

Other Functions of Septic Tank.

In the foregoing observations the septic tank has been regarded merely as an agent for the destruction of solid matter, but the experience which has been gained with it in dealing with a large number of sewages, differing widely in their composition, shows that it performs a number of other functions which are hardly less important.

Mr. Cameron's own view of these is set forth in the course of his examination by Professor Foster:

"Are you at all inclined to think that there are special changes taking place in your septic tank, not merely the general diffusion of several parts of the sewage as it comes in, and not simply the mere solution of the solid matters, but changes by which the material of the sewage is made, so to speak, easier to be worked upon by the organisms in the filter?—My view is that the water between the two layers, the top layer and the bottom layer, is undoubtedly acted upon in its passage through the tank. [D. Cameron, 2014.]

"Quite so; beyond mere solution of visible particles, or are you speaking only of the solution?—I am speaking now of the parts in solution. [2015, 2016.]

"Then the material in solution is acted upon?—Then the material in solution is acted upon. [2017.]

"And that action is of such a character as to facilitate the subsequent action of the filter?—Yes; undoubtedly the ammonias are increased—an unstable condition is set up." [2018.]

Dr. Barwise, referring to the effluent from the Exeter septic tank, says:—

"I found the Exeter tank effluent contain a trace of nitrites too. I think it makes it a very favourable effluent—to nitrify." [Barwise, 4032.]

Purification effected by Septic Tank.

Dr. Rideal, being asked by the Chairman to give an example of the changes that are effected anaërobically in practice, replied as follows:—

"With the Exeter tank, in 1896, I obtained the following results:—

"*Parts per* 100,000.

—	Total solids in solution.	Oxygen consumed.	Free NH_3.	Alb. NH_3.	Nitrite.	N. as Nitrate.	Total N.	Organic Nitrogen.
Raw sewage, Nov. 3, 4	46·8	6·56	3·6	1·40	0·0	0·0	7·4	4·4
Tank effluent, Nov. 4, 5	48·6	4·32	4·9	0·64	trace	0·04	6·24	2·2

PURIFICATION EFFECTED BY SEPTIC TANK—*continued.*

"From the above results it will be seen that the changes produced by the passage of the sewage through the tank may be summarised as follows:—

1. A marked increase in the total solids in solution or fine suspension.
2. A reduction of about 33 per cent. of the organic matter, as measured by the oxygen consumed.
3. An increase of about 33 per cent. in the free ammonia.
4. A reduction of about 54 per cent. in the organic or albuminoid ammonia, or 50 per cent. in the organic nitrogen.
5. A slight production of oxidised nitrogen, and disappearance of a small amount of the total nitrogen.

"It is, therefore, evident that the septic tank, by means of its bacteria, enzymes, or spontaneous chemical decomposition, materially alters the composition of the raw sewage. The increase in the total solids points to a solvent action of the water on matter in suspension, and this may be due to a digestive or to a purely physical process; but the marked disappearance of organic matter, and transference of the nitrogen from the organic condition to that of free ammonia, is undoubtedly due to bacterial influences." [Rideal, 4135.]

He also gives the mean results of a second set of analyses which he made in November of the same year:—

Parts per 100,000.

—	Total solids in solution.	Oxygen consumed.	Free NH_3.	Alb. NH_3.	Nitrite.	N. as Nitrate.	Total N.	Organic Nitrogen.
Filtered samples—								
Raw sewage, Nov. 13, 14.........	55	3·61	8·5	4·3	trace	0·02	12·82	5·8
Effluent, Nov. 14, 15...............	59	2·73	11·2	2·66	trace	0·022	14·92	5·7

"It will be seen that the above results give the same general conclusions as were arrived at from the former series, viz., an increase in the total solids, 25 per cent. of organic matter destroyed, an increase of 33 per cent. in the free ammonia, and a decrease of 38 per cent. in the albumi-

PURIFICATION EFFECTED BY SEPTIC TANK—*continued.*

noid ammonia. The total nitrogen, however, in this series shows a slight increase due to the larger amount of ammonia found in the effluent, or summarising :—

—	Purification effected by Tank.	
	Oxygen consumed.	Albuminoid Ammonia.
1st series	33	54
2nd series.....................	25	38
Mean	29 %	46 %

"... . The septic tank seems therefore to effect as much purification as an average chemical precipitation process, or as slow upward filtration. It will be further noted that both sets of experiments show an increase in the total solids in solution of from 4 to 8 per cent., and this can only be explained on the hypothesis that the solid fæces and other matter in suspension pass into solution in the septic tank." [4135.]

It should be noted that the first set of analyses relates to samples containing suspended matter, while for the purpose of the second series this was removed by filtration, so that the figures relate to the dissolved matter only.

Mr. Whittaker gives the average purification effected by the septic tank at Accrington, measured by the albuminoid ammonia and oxygen absorbed, as roughly 50 per cent. [Whittaker, 5728.]

The work done by the open septic tank at Leeds during the year ending January, 1900, is shown by the following table, put in by Colonel Harding [7257] :—

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen absorbed (4 hours, 80° F.).
Crude sewage	120·8	44·4	2·15	1·02	9·08
Septic tank effluent (No. 1)	77·6	13·1	1·83	·455	4·18
Purification effected	—	70 p.c.	14 p.c.	55 p.c.	53 p.c.

Purification effected by Septic Tank—*continued.*

The witness, however, was of opinion that, "apart from the reduction in amount, and the fine division of the suspended solids," the action of the septic tank does not facilitate subsequent filtration. [7262.]

Mr. Mawbey gives some extensive tables, showing the average percentage purifications obtained at Leicester by various combinations of processes. Those effected by the closed detritus tank and septic tank together were :—

—	Suspended Matter.	Albuminoid Ammonia.	Oxygen absorbed at 80° F. in 4 hrs.	Int. Rep. Vol. II.
Combination No. 10..	83·01	62·14	60·67	p. 440
,, 11..	74·14	45·85	42·17	p. 441
,, 13..	72·08	58·94	36·20	p. 442
,, 8..	71·96	46·72	40·73	p. 446
,, 15..	71·64	46·205	44·51	p. 449

A clear exposition of the value of the septic tank in its relation to the subsequent treatment was given by Mr. Fowler :—

"Have you formed any opinion as to whether the anaërobic action of the septic tank facilitates the subsequent filtration apart from the reduction in suspended matter to be dealt with?—I have not the least doubt that it greatly assists nitrification." [8407.]

"Then your opinion is that septic tank action is useful in promoting the changes which come about in subsequent filtration?—That is certainly my opinion. [8410.]

"Would you mind telling us in your own words what you consider from your recent experience to be the value of septic tanks?—One of the first things in which a septic tank appears to be valuable is that it mixes the sewage as it comes down from hour to hour, and produces an effluent of a much more equable composition to go on to the bacteria beds, so that these are not subject to very considerable extremes, either in the way of acidity, or alkalinity, or whatever it may be, according to the material that comes down. And, further, what we have found in Manchester I think should

Purification effected by Septic Tank—*continued.*

be noted, and it is this, that in the septic tank apparently the process which goes on has a tendency to so disintegrate the suspended matter that it is very much more easily retained on the surface of the bed, or if it penetrates does not hold the water to the same extent. That is to say, if you take a bottle of crude sewage, or even of simply settled sewage, the suspended matter floats about in it in a sort of emulsion, and does not show any tendency to settle; if, on the other hand, you take septic tank effluent it may be very black in appearance, worse perhaps at first sight than settled sewage, but if it is allowed to stand in the bottle for a short time all this black suspended matter settles down quite cleanly to the bottom, and leaves a fairly cloar effluent to be dealt with on the bed, and this suspended matter when it gets on to the bed allows the water very readily to penetrate through it. [8411.]

"Another advantage of the septic tank is that it digests, as you suggest, 25 per cent. of the suspended solids in the sewage?—That is so. [8412.]

"And there are no chemicals to swell the volume of the sludge?—And no cost in chemicals. And then there is this further. I think it can be shown, although our experiments at present are only very preliminary, I think we shall find that the actual chemical changes which go on in the septic tank are anaërobic changes, such as to produce compounds which are readily oxidised by subsequent treatment on the beds. I think that it is probable that it is easier to break down sewage matters by preliminary anaërobic action, followed by oxidation, than if the process is throughout one of oxidation. That is our experience." [8413.]

Similar conclusions arrived at by tho Leeds Sewerage Committee as the result of their experiments at Knostrop are set forth in their report:—

"Briefly, the advantages found in the use of septic tanks were:—

"1. The production of a practically uniform effluent from sewage of such varying composition as that of Leeds.

"2. The digestion of part of the solids in suspension, which at Leeds amounted to about 40 per cent. of those originally in the sewage.

"3. The anaërobic putrefaction, which takes place in the septic tank, facilitates subsequent filtration, rendering the

Purification effected by Septic Tank—*continued.*

filtrate less liable to secondary putrefaction." [City of Leeds Report on Sewage Disposal, July, 1900, p. 85.]

The average percentage reductions effected by the septic tank at Leeds during twelve months' working were—Suspended solids, 71 per cent.; albuminoid ammonia, 61 per cent.; oxygen absorbed, 50 per cent. [*Ib.*, p. 79.]

Dr. Frankland's opinion on the subject was more guarded:—

"Then do you think that the septic tank anaërobic treatment is of value in preparing organic matter for the aërobic action in the contact beds?—Well, I do not think that any very decisive experiments have been made on that subject; it is more inference and *à priori* reasoning than anything else as far as I know." [Frankland, 9969.]

"(Colonel Harding): Do you think that the good results that you have obtained from your beds with this mixture of domestic sewage and trade refuse may be due to the fact that you have as a first process septic tanks, which septic tanks have probably a capacity of twenty-four hours' supply, and therefore they do give you the uniformity which you have been desiring?—Yes. (Mr. Platt): That is just what they do?—(Mr. Stenhouse): Undoubtedly the septic tank does give that uniformity." [Stenhouse, 12408.]

"And I strongly recommend what I call an equalising tank, which is really a septic tank, in all cases where trades refuse of any large volume has to be treated along with sewage matter." [Ashton, 12450.]

At Birmingham, with roughing tanks and open septic tanks, holding about eight hours' dry-weather flow, the following results were obtained. [Third Rep., vol. II., pp. 208, 209.]

Parts per 100,000.

—	Suspended Solids.	Alb. Amm.	Oxygen Absorbed.	
			Including Suspended Matter.	Excluding Suspended Matter.
Computed average sewage	67·6	1·66	15·32	7·61
Tank effluent	24·5	1·06	10·77	6·85
Percentage reduction	63·7	36·1	29·7	10·0

It has often been stated that the septic tank would only work with a weak sewage. A remarkable instance to the contrary is contributed by Mr. Stoddart. [Int. Rep., vol. II., p. 291.]

ANALYSES OF SEWAGE EFFLUENTS PRODUCED BY STODDART'S PATENT FILTER.

Results expressed in Grains per Gallon.

—	EXCEPTIONALLY STRONG SEWAGE, OCT. 20TH, 1899.		
	Sewage.	Tank Effluent.	Filtrate.
Saline ammonia	35·63	10·08	6·3
Albuminoid ammonia	9·45	·77	·26
Nitrogen as nitrates and nitrites	none	none	1·50
Oxygen absorbed, 4 hrs. at 80° F.	23·10	3·50	1·47
Appearance	opaque	opalescent	turbid with clinker débris, rapidly clears.
Odour	sewage	sewage	slight, earthy.

Percentage Purifications reckoned on Crude Sewage.

—	By Septic Tank.	By Filter.	Total.
Saline ammonia	71·7	10·6	82·3
Albuminoid ammonia	91·9	5·4	97·3
Oxygen absorbed, 4 hrs. at 80° F.	84·8	8·8	93·6

It will be seen that the reduction of impurity effected by the septic tank is from 7 to 17 times as great as that by the Stoddart filter. This result is so extraordinary that one might well hesitate to accept it had the analytical figures been vouched for by any less authority than Mr. Stoddart.

Maturing of Septic Tank.

The work of the septic tauk being biological, and not mechanical merely, it follows that it will not attain its full efficiency until sufficieut time has elapsed to cultivate the proper bacteria in the requisite numbers.

Mr. Mawbey was questioncd by Colonel Harding as to the length of the period required to bring this about:—

> "Were you able to notice in this closed tank how long it was before the septic conditions did arise?—Oh, they began in about three weeks; about from a fortnight to three weeks; if it was hot weather they began sooner than in the cold weather." [Mawbey, 8171.]

An instance of much slower maturing was cited by Mr. Fowler:—

> "Then how long did you find that the tank took before evident septic conditions appeared?—Speaking from memory, I think it would be about some three months before there was any appearance, any prolonged appearance, of scum. It depends somewhat on the weather, of course. In the course of a few days it will begin to give off gas, but it will be by no means thoroughly septic before some months. [5518.]
>
> "How soon did you find that scum, to any extent, appeared on the septic tank?—Speaking agaiu from memory, I think—well, the septic tank was started in February; the scum appcared in May—I think it was after the Local Government Board iuquiry, as far as I can recollect." [5522.]

Mr. Fowler also produced analyses showing how the effluents from the filters were affected by the condition, as to maturity or otherwise, of the tank from which they were supplied:—

> "There is only, I think, one other point. I notice that if you take the quarter ending September 26th and the quarter December 26th, in the first case the quarter is warm weather, you have 1 in 2 of the effluents in the coarse beds A and C putrescible; aud in the cold weather, iu the quarter ending Decembcr 26th you have only 1 in 16 putrescible?—Certainly. [8547.]
>
> "And the same thing holds good for the effluents from bed B, practically speaking; was that due to the great

MATURING OF SEPTIC TANK—*continued.*

dilution in winter, or what was it?—No, I think it admits of a simple explanation, namely, that during the earlier period our septic tank effluent did not come thoroughly into condition. That is one of the results which leads me strongly to the opinion that you require to have a thoroughly septicised effluent to get very good nitrification." [8548.]

A similar experience was noted at Leeds:—

"Describe to us briefly the development of action in a septic tank?—When a septic tank is first started, a simple settlement of suspended matters takes place, and the effluent is similar in colour to the sewage, being in fact mere settled sewage. Several weeks pass before there is in Leeds sewage any fermentation in the tanks. Then bubbles begin to arise, slowly at first, and after two or three months more actively, until about the fourth month accumulations of gas in the deposit come up at intervals with considerable violence, lifting with them masses of the black deposit to the surface." [Harding, 7246.]

An important corollary of these considerations was pointed out by the same witnesses:—

"Then if it takes several months to develop septic conditions, it would appear to be a disadvantage to empty septic tanks when accumulations arise, because in that case you have to begin *de novo* and lose many weeks before the full septic condition is developed?—That is so." [Fowler, 5521.]

"Then do the tanks sooner or later require emptying?—Yes; but it would be advisable where possible not to empty and clean out septic tanks, obviously because it takes months to get a tank into working order. It is much better, where it can be done, and it can generally be done in small tanks, to remove at intervals some of the deposit through a valve. Only a small quantity at a time could be so removed, but in this way the tank might go on working uninterruptedly." [Harding, 7252.]

(The writer has for many years past adopted this plan in all the works (large as well as small) which he has had to design, with very satisfactory results.) See also 7287.

EFFECT OF TEMPERATURE ON WORK OF SEPTIC TANK.

"I think the action is much more rapid when the sewage is fairly concentrated and when the weather is warm." [D. Cameron, 1896.]

"So that any defect in seasonal activity arising from temperature is equalised and made up by an excess in favouring circumstances of warm weather, probably?—Yes, that is another of the smoothing influences of the tank, of storing during cold or wintry weather, and then a more rapid decomposition during warm weather. I may say that all the temperatures I have got of the inside of the tank are more uniform than those of the external atmosphere." [2068.]

"Did severe frosts affect the working of the septic tanks?—No. Even in hard frost there appeared to be no appreciable deterioration of effluent. On one occasion the scum was frozen hard enough to bear walking upon, and we had several heavy falls of snow. The temperature of the effluent was always well over freezing point. The scum is useful as a non-conductor to conserve the heat of the sewage in the tank." [Harding, 7258.]

"I should be quite prepared to find the increase of temperature (caused by blowing in steam) would increase septic action." [7329.]

"Have you noticed any difference between summer and winter working?—No, as far as the purification of the sewage goes, the difference that we have found is simply in the amount of recovery which takes place in the beds during the periods of rest, and that appears to be less in the winter than in the summer. [Fowler, 8432.]

"I am speaking of the septic tanks, not of the beds. Does the action appear to go on more or less fast in the summer than in the winter, or have you any data?—Speaking from ordinary observation, I should think it would go on rather faster in the summer. It does not seem to be very much faster. [8433.]

"(Colonel Harding): Do you not think that if you kept it at a temperature of 80 degrees you would get more active septic conditions?—No doubt it could be kept to that, but the smell is not much greater in tho summer than in the winter." [8434.] Seo also 5552 *et seq.*, 7245.

Septic Tanks in Series.

Some attention was paid to the question of arranging septic tanks in series, and passing the effluent from each through one or more others in succession. Such an arrangement was tried at Accrington, and was referred to briefly by Mr. Whittaker:—

"Then I may take it, Mr. Whittaker, from your experience here, that it is convenient to work septic tanks in series?—Most convenient; chiefly from the point of view of removal of the sludge. [5711.]

"If you remove this denser sludge from the earlier tanks of a series you find, I suppose, that in the later tanks there is very little accumulation of sludge, and removal of sludge from the later tanks is only required after very long intervals?—That is so. [5712.]

"Now, have you found any advantage by working the tanks in series in this respect: that you obtain less solids in suspension in the final effluent than you would do if each were worked independently?—Yes, I believe that is so. [5713.]

"You think that you can obtain, working them in series, a reduction in the solids in suspension in the final effluent?—In the tank effluent and also in the final effluent." [5714.]

"What is the advantage of tanks used in series?—The advantage that we expected to find was that we should get an effluent more free from suspended solids, but we were disappointed. It would, of course, be an advantage if all suspended solids could be left behind, for the rate of filtration could then be considerably increased. We found that, worked in series, the deposit was mostly in the first tank, and that was the only one that formed a scum. There was less deposit in the second tank, and still less in the third, and these later tanks are likely to go for years without necessarily removing deposit. By working in series, and the first tank being in duplicate, the removal of septic sludge is facilitated. There does not appear to be otherwise any advantage." [Harding, 7249.]

"The analyses I made some time ago show there is practically no difference between the three in series taken together with the 24-hours flow and the ordinary 24-hour tank." [Harrison, 14949.]

"Then if there is no difference in the final result, are there any other reasons giving an advantage to this system of series?—Yes. [14951.]

"What are they?—The greatest aecumulation of sludge takes plaee in the first tank; and this is confined to a, eomparatively speaking, very small area, whieh, of eourse, is an advantage in eleaning." [14952.]

See also 8393 *et seq.*, 14495.

Tank Capacity in relation to Flow.

The question of tank capaeity has reeeived considerable attention at the hands of the Commissioners. Mr. Cameron was the first witness to be examined on the subject:—

"Praetieally, what length of time do you think ought to be allowed for the fermentation process by which the solids are liquefied?—The time of stay of sewage in the tank varies with the flow; and ordinarily if the flow is 53,800 gallons per day, the stay of the sewage in the tank, from the time it enters to the time it leaves again, is 24 hours. I found 18 to 20 hours' stay in the tank as the best condition for filtration. . . . . The scum is formed at the top and the deposit at the bottom, and that gets a very much longer period to be worked upon than the sewage containing tho matters in suspension that also undergoes a certain change in its passage through the tank. [1895.]

"The time would vary, I suppose, with tho strength of the sewage and the warmth of the weather?—Undoubtedly. I think the action is much more rapid when the sewage is fairly concentrated, and when the weather is warm." [1896.]

"(Major-General Carey): What relation does the eapaeity of that eultivation tank bear to the dry-weather flow at Caterham, or any typical ease?—Well, the arrangement was very much the same as that of Mr. Cameron's—24 hours' supply; but apparently the provision of the stones makes, I think, it possible for this capacity to be very considerably reduced." [Scott Moncrieff, 3394.]

"Have you formed any opinion as to a septie tank as to the time the sewage should remain in the tank—that is to say, the rate of flow?—I ean only tell you from what I see they are doing at the various works. What I try to get is

TANK CAPACITY IN RELATION TO FLOW—*continued.*

24 hours' capacity at least for a septic tank. [Tatton, 6712.]

"You have not of your own knowledge any information as to the advantages to be derived from letting it remain longer or shorter?—No, I have not got that information." [6713.]

"If the rate of flow is too fast, the tank is a mere settling tank, and becomes full and requires emptying before septic conditions have had time to develop. The difference between a settling tank and a septic tank is one of speed of flow only. We found that the 24-hour rate was the best, such rate of flow as would fill the tank in 24 hours. Put another way, the septic tank should be of such capacity as to contain 24 hours', or one day's sewage. Twice this speed (12-hour rate, or half-day sewage capacity) permitted septic conditions to develop, but brought away too many suspended solids in the effluent. Half the speed (48-hour rate, or two days' sewage capacity) gave no better results as to the liquid part of the effluent than the 24-hour speed, and there was too little advantage in the slightly reduced quantity of suspended solids brought away in the effluent to make it worth while on that account alone to double the area of tanks. . . . . Briefly, then, my opinion on this point is (1) that any capacity less than half a day's supply is too small to give time for septic conditions to arise; (2) that a capacity of one day's supply is practical, and that a larger capacity does not give any appreciably better effluent; (3) that larger capacity, say, two or three days' supply, while not giving much better effluent, may probably bring about a rather larger digestion of the deposit left in the tank." [Harding, 7247.]

"I think you hold the opinion that if sewage is to be treated by artificial filtration to the extent of six times the normal dry-weather flow, it would be well that the septic tanks hold twice the normal flow?—I think it is desirable. [7350.]

"Desirable?—Yes; on these grounds, that if you have a normal flow of, say, 24 hours, and you increase that by six times, you will bring out more suspended solids, especially in the first rush after a storm, than your filters can deal with." [7351.]

Tank Capacity in relation to Flow—*continued.*

"And the stay in the septic tanks is, roughly, eight hours?—That is so. [Watson, 14499.]

"Is that sufficient with your sewage to fully develop septic conditions?—It is; it is a sufficient stay. I ought to add, that after the sewage passes through the septic tanks it enters a large conduit, 8 feet in diameter, which conveys the bulk of the sewage right down to the extreme limit of our property, and that conduit is to all intents and purposes a closed septic tank, so that we have a further septicisation of the sewage after it leaves our works. [14500-1.]

"But what would be the stay in the conduit; it would be very short, would it not?—About six hours, perhaps." [14502.]

"Nos. 1 and 2 are working on the 24 hours flow; No. 3 on 72 hours flow. [Harrison, 14925.]

"Are there any differences, and marked differences, in the effluent from No. 3, as compared with Nos. 1 and 2?—I suppose Nos. 1 and 2 are about the same. They are both alike. [14926.]

"Does No. 3 differ from Nos. 2 and 1?—Yes, the figures are lower throughout." [14927.]

See also 2061 *et seq.*, 4788, 5488, 5502, 6528, 7260, 14808.

It may be noted that for some time after the introduction of the septic tank the Local Government Board were accustomed to require a capacity of one and a half days' dry-weather flow. This has since been successively reduced to one and a quarter days and one day.

It has sometimes been assumed that the longer sewage is kept in a septic tank the better will be the result. Mr. Scott Moncrieff, however, is of opinion that too much anaërobic action is undesirable.

> "You may have an anaërobic change carried further, or an anaërobic change carried not so far, that may possibly give better results, and it is upon this question of the best point at which to arrest or continue the anaërobic fermentation that I am now working." [Scott Moncrieff, 3200.]
>
> "It was also an important thing to discover if the anaërobic change could be carried too far, with a view of finding out if you could kill off all the aërobic organisms or the organisms which may be capable of doing their work by too

Tank Capacity in relation to Flow—*continued.*

high an anaërobic condition, and that I am glad to say I have succeeded in proving. The anaërobic change was carried to a point at which the nitrification was completely suspended." [3242.]

"And what happens if the limit of free ammonia is passed?—That I am not prepared to say. All that I can argue is that there is some limit in the matter of free ammonia, and that you can get ammonia to such a point, produced bacteriologically, through the agency of anaërobic fermentation, that it may become toxic to the nitrifying organisms; but what point that is I am not prepared to say." [3251.]

"When you speak, as I think you do, of the possibility of your anaërobic action being too great, do you mean that it produces undesirable ammonia compounds?—I divide that into two points in my evidence, sir. Obviously you may have the ammonia too high for the work of nitrifying organisms. [3375.]

"What is the evidence of that?—Well, I do not say that I have yet obtained it from sewage, or I do not say that sewage may produce it; but there may be something in that direction which I have not been able to identify. All I can say is that, taking one thing with the other, I have arrested the whole process, and brought it to a standstill by carrying the anaërobic change too far. That I have succeeded in doing, and Dr. Rideal, as a matter of fact, is engaged upon . . . ." [3376.]

The opinion expressed by Mr. Scott Moncrieff as to the undesirability of carrying the anaërobic action too far, is supported by Dr. Sims Woodhead and Dr. Fowler:—

"I think the anaërobic change must come first, but must be stopped at a certain stage." [Sims Woodhead, 2836.]

"Some difference of opinion, indeed, exists on the data already available, the point of discussion appearing to resolve itself into a question of the conditions and limitations of septic action. There is no doubt, for instance, that if certain septic tank effluents are kept in a closed bottle they develop H_2S, become exceedingly offensive, and deposit considerable quantities of matter originally in solution. An effluent in such a condition may be termed 'over-septicised,' and there is no doubt that it is possible to hold sewage too

TANK CAPACITY IN RELATION TO FLOW—*continued.*

long in the septic tank, when nuisance is apt to arise and the effluent is very difficult subsequently to purify on anaërobic (*sic*) beds. There is some evidence that toxic products, *e.g.*, amines, are formed; the H_2S and other gases present also quickly use up tho oxygen supply in the filters.

"But at present, I am bound to say, analytical methods have not been developed enough in the direction of determining when a septic effluent is in the best condition for subsequent purification. Possibly the composition of the gases evolved from the tank may give some indication, but these arise chiefly from the solids, and have no necessary reference to the condition of the liquid. Thus, if the flow through the tank is very irregular, the liquid may be over-septicised at one time and not enough at another, while the procoss remains the same in the deposited sludge throughout." [Fowler, Manchester Lecture, p. 15.]

Mr. Scott Moncrieff's explanation, in Answers 3251 and 3375, of the manner in which nitrification is interfered with is very interesting. The object of anaërobic treatment, so far as the liquid portion of sewage is concerned, is to prepare the nitrogenous matter for filtration by converting its nitrogen into ammonia. It might have been expected that the more completely this change could have been effected the better, but it appears that an excess of food is actually harmful to the nitrifying bacteria, and that in dealing with a very strong sewage it may be advisable to cut short the anaërobic treatment before it has done its full work.

Mr. Scott Moncrieff, however, goes on to say:—

"I am very much inclined to think that these ammonia limits will not in all probability come into practice unless in exceptionally strong sewage. What I mean is, that there will be no ordinary sewage that is so very strong that it will be outside the limits as regards ammonia. I hope to be able to speak positively about this very soon." [3255.]

It is possible that there are other considerations involved besides the amount of ammonia. Thus the same witness refers to

"the formation of compound ammonias which are highly toxic in their character, and fatal if in excess to the working of any organisms in the future process." [3242.]

TANK CAPACITY IN RELATION TO FLOW—*continued.*

Mr. Scott Moncrieff expressed the opinion that in dealing with a very strong sewage the difficulties due to the toxic qualities of the tank effluent might be overcome by dilution. He considered that this should be effected after the sewage had undergone its anaërobic fermentation, and before it was subjected to the nitrifying process, so that the oxygen contained in the diluting water might be available at the proper time. [3252.]

The question of tank capacity cannot safely be treated as if it were merely a matter of subjecting the liquid portion of the sewage to anaërobic treatment for a given number of hours. It would be a still graver mistake to lay down a hard-and-fast rule on the subject, regardless of variations in the strength and condition of the sewage. To take a single aspect of the case, the sewage of a large town almost invariably undergoes on its way through the sewers to the outfall a process of mechanical attrition and disintegration, together with one of bacterial decomposition and hydrolysis.

The sewage of a mansion or public institution, on the other hand, generally finds its way into the septic tank within a very few minutes of its production, and in an absolutely fresh and unbroken condition, leaving the tank bacteria to do the work which, in the other case, is performed in the sewers. This consideration, which is mentioned by Colonel Harding in his evidence quoted on p. 81, must obviously be taken into account in deciding on the capacity to be adopted in any particular case.

The question is one to which the writer has devoted considerable attention during the past few years, and while he has been able to detect no great advantage from keeping an ordinary sewage in a septic tank for more than about twenty-four hours, he has not, on the other hand, found any reason to apprehend any marked falling-off in the purification where a longer stay is afforded. The absence of any deleterious results in such cases appears to be explained by the following extract from Dr. Rideal's answer 4140:—

> "In a solution so dilute as a sewage the influence of the products (of decomposition) would hardly be felt. . . . Still, the action is more energetic when the products are removed as formed, and the bacteria supplied with fresh food." [Rideal, 4140.]

Tank Capacity in relation to Flow—*continued.*

The subject is so complex, and the reliable data thereon are so meagre, that it is impossible to formulate any definite conclusions which can be wholly justified on theoretical grounds. For practical purposes, however, it is safe to assume that a tank in which the sewage can come so near to a state of absolute rest as to permit the separation of practically the whole of the solids, and which affords room for their retention until the putrescible portion has disappeared, will also as a rule give the liquid all the preparation which it needs for its subsequent filtration.

A consideration which is sometimes lost sight of is the disturbing action of the inflow. With large tanks serving sevoral thousand people, it is easy so to arrange the inlets that the incoming sewage shall come to rest within a very short distance; but with smaller tanks this is often a difficult matter. In a tank serving a good-sized village, the discharge of a flushing-tank on the outfall sewer may easily cause such a disturbance as to dislodge and carry into the outflow an appreciable quantity of the deposit which lies on the floor, while in still smaller tanks, serving single mansions, the flush from a bath or washtub will often have the same effect. The filters consequently become coated with a layer of partially-decomposed organic matter, leading not only to a falling-off in their efficiency, but also in many cases to something approaching nuisance. The trouble may, of course, be avoided by the use of proper settling chambers with or without automatic means for removing deposit.

The liability in small tanks to the washing out of solid particles, and the freshness of the sewage with which they generally have to deal, indicate the desirability of making the tank accommodation for small flows on a more liberal scale than is adopted in the case of cities and towns.

The failure to recognize this has been a fruitful source of trouble in connection with the smaller works.

In the case of hospitals for the treatment of diseases the infection of which is waterborne, it may perhaps be desirable to prolong the stay of the sewage in the septic tank considerably beyond what would be considered necessary for its chemical purification, with a view to tho more complete destruction of disease germs, in which the *duration* of exposure to adverse influences is now recognized as an important factor.

This branch of the subject, however, is still wrapped in some

obscurity, and it is by no means certain that the purification processes, as ordinarily carried out, do not for practical purposes afford all the protection which is required.

An excessive stay in the tank may impart to the effluent more smell than it would otherwise possess; but if it is conceded that the work of the tank consists in breaking down stable into unstable compounds, it is by no means certain that such smell, though doubtless objectionable in certain situations, is not a sign that the effluent is in the best condition for further treatment.

OPEN *versus* CLOSED SEPTIC TANKS.

When Mr. Cameron first placed the septic tank before the world, he pointed out that, while in many cases it might be advisable to cover the tank, there would probably be others in which it might be found practicable to dispense with this precaution.

This point was raised by Professor Ramsay, who asked if he had noticed whether anaërobic fermentation would go on in open tanks. Mr. Cameron replied:—

> "I think it will. My first idea was to use only an open tank and not a covered tank, and so long as the scum is formed on the surface, I think anaërobic fermentation is going on." [1937.]

Professor Ramsay then asked:—

> "Does anaërobic fermentation ceaso when the scum is destroyed?—I do not think it does; the production of gas does not cease." [1938.]

Mr. Cameron's suggestion that it might be possible to dispense with the covering of septic tanks has been followed up in several quarters, notably by the Corporations of Manchester and Leeds, both of whom have carried out extensive experiments with open tanks. The results at both places appear conclusively to confirm the opinion expressed by Mr. Cameron that in certain cases no other cover would be required than the natural one afforded by the scum:—

> "Did you find any material difference in the results of the closed septic tank as compared with the open septic tanks; how did the effluents differ in each case, if at all?—Chemi-

Open *versus* Closed Septic Tanks—*continued.*

cally, they were as near as possible identical. [Fowler, 5493.]

"And in appearance?—And in appearance also." [5494.]

"What opinions have you formed of the relative value of open and closed septic tanks?—The question whether septic tanks should be closed or not is of importance in view of the considerable extra cost of roofing them in. The advantages claimed for closed tanks are:—

(1) That the roofing excludes the air from the surface, and promotes better anaërobic conditions.
(2) That the resultant gases are under control, and can be utilised for lighting or heating.
(3) That evil odours are prevented from escaping.
(4) That the heat of the sewage is better maintained.

"The experience of Leeds shows that whatever results were obtained from the closed septic tanks, were equally well obtained by the open, and that the scum which forms on septic tanks itself soon gives a cheap automatic roof, which is chiefly of value in preserving the heat in the sewage, the floating surface being a bad conductor. It was found that the average loss of heat of the sewage in passing through the open septic tanks was 1·6° F., while through the closed it was ·8° F., and the difference is too small to warrant the expense of a roof on this account. The heating value of the gases is not great, and the roofed-in septic tanks are really gas holders, and except under proper care, may become a serious source of danger. In the open septic tanks the gases produced are at once dispersed. For the most part they are inodorous, no appreciable nuisance having arisen, though the effluent itself is more or less offensive. But Leeds sewage is diluted and mixed with trade effluents, and no doubt where strong domestic sewage is being treated, greater nuisance may arise, and the roofing become necessary, though it would only be effective if the gases were burned. In appearance, the effluents obtained from the open and closed septic tanks were identical, whilst from a chemical point of view no distinct difference can be detected." [Harding, 7245.]

"Prior to our experiments at Manchester, there was, I believe, a general impression that septic tanks must be closed to secure anaërobic conditions, but our experience of

OPEN *versus* CLOSED SEPTIC TANKS—*continued.*

fermentation phenomena led us to think that no such artificial exclusion of air was really necessary, and in comparative experiments made with open and closed tanks it was conclusively shown that equally good results were obtainable with both. The covering of septic tanks may frequently be desirable, however, on other grounds, viz., the avoidance of smell and possibility of gas collection." [Dr. Frankland, 9927.]

The comparisons drawn in these two cases between closed and open tanks, particularly as regards the reduction in suspended solids, are of little practical value, inasmuch as the experiments were in neither instance conducted in such a way as to afford comparable results. In particular, the closed tanks were in both cases very much smaller than the open ones, being so short, in fact, that the disturbance, slight as it is, caused by the inflow, could not subside in time to prevent the washing out of more deposited matter than would escape from a similarly constructed tank of larger size. Hence the comparison may more fairly be regarded as one of small and large tanks than as one of closed and open tanks.

Other witnesses testified as follows:—

"Have you any experience of septic action in open tanks—uncovered?—No, but I have read descriptions of processes. I quite believe that septic action does take place in the open tank which is uncovered, provided the liquid is very still at the top, and covered over with a felt." [Rideal, 4463.]

"Have you formed any opinion as to the necessity of covering septic tanks at all?—No; my impression is, from what I have seen, that we get rid of a very large quantity of matter indeed in an open tank if you only give it time to pass through. [Latham, 4641.]

"In tanks, if they are left open for any length of time, decomposition takes place, and a layer, perhaps a foot deep, of frothy, offensive matter accumulates on the surface of them. I have seen in the case of the Burton tanks, when they were formerly at work, a layer there that the sewage used to ferment from the character of the sewage itself, from the washing of the beer barrels going into it; it used to ferment, and you would get a sort of barm on the top of the filters over two feet deep. [4642.]

Open *versus* Closed Septic Tanks—*continued.*

> "Which in a way acted as a roof?—Of course; but still, it was very disagreeable, the smell coming off this decomposition going on." [4643.]

> "There is no necessity to roof in so far as the decomposition is concerned. The oxygen does not readily pass into the body of the water." [Whittaker, 4801.]

> "Apart from the possibility of consuming the gas, you do not see much use in a roof, do you?—No, I do not think there is." [Tatton, 6746.]

The adoption of closed tanks rather than open ones has generally been due, not so much to any doubt as to whether the liquefying action would take place in the latter, as to certain practical considerations, some of which have already been referred to, but which may with advantage be briefly recapitulated here. They are: the maintenance in a covered tank of a uniform temperature, and particularly the avoidance of extremes of cold; the protection afforded by the roof against undue disturbance of the scum by wind and rain; and the prevention of fly-borne infection, and of nuisance from the exposure of the sewage. This last consideration is recognised even by those who have successfully treated sewage in open tanks, such sewage having as a rule contained a large proportion of waste water from manufacturing processes, some kinds of which have a marked effect in checking smell therefrom. (See pp. 114, 115.)

Dr. Rideal, after enumerating some of the odorous compounds which are evolved from sewage, and which he classifies as being "mainly of two types—amines and sulphur compounds," goes on to say:—

> "Therefore the preliminary liquefaction should be conducted in a closed chamber." [Rideal, 4146.]

In view of the exaggerated statements which have been made as to the cost of covering a septic tank, it is interesting to note an engineer's opinion on this point. Asked whether his experience would enable him "to express a preference either way for open or closed septic tanks," Mr. Strachan replied:—

> "I have no direct experience, but my preference goes for closed tanks. I think such a thing closed up is better than open, and the cost is not much to put a light roof on." [7523.] See also 8414.

In a case in which the writer was concerned some years ago,

where four septic tanks were laid down to serve a population of 10,000, the total cost of covering them was £216 3*s.* 4*d.*, or just over 5*d.* per head. This seems little enough to pay as an insurance against nuisance, seeing how much has often been spent for the same purpose on long outfall sewers and pumping plants to carry the sewage further afield.

Smell from Septic Tank.

The question as to smell from septic tanks was fully gone into:—

> "There are changes going on which must necessarily, if the changes are going on properly, lead to the production of a certain amount of smell. [Woodhead, 2977.]
>
> "Was there anything amounting to the likelihood of a public nuisance?—No; I do not think so in either of them." (Contact beds at Claybury and closed septic tank at Exeter.) [2978.]

Mr. Whittaker, referring to the "spongy mass" which on still days covers the surface of the Accrington tanks, said "it had scarcely any odour; practically no odour" [Whittaker, 4796], and at the close of his evidence, on being asked by Colonel Harding,

> "You are not afraid of any smell arising from a very large septic tank?" replied, "Not the slightest. I think the smell from pressed sludge is far more excruciating." [4957.]
>
> "(Chairman, Colonel Harding): I omitted to ask you if you had found any nuisance arise from smell from this septic tank dealing with these 2,000,000 gallons?—Only, I think, in certain conditions of the atmosphere. If you have a very quiet, muggy night, so that the gases cannot get away, and are held over the surface of the tank, then there is rather an unpleasant odour about it; but on a day like to-day—well, the Commissioners could tell for themselves that there is practically no odour." [Fowler, 5571.]
>
> "You would say that an open septic tank was a nuisance? —Undoubtedly." [Chatterton, 6440.]
>
> "And you could not say that if this tank, which was objectionable when it was open, had had a roof over it, it

SMELL FROM SEPTIC TANK—*continued.*

would have been objectionable or not?—I should think it would not." [6447.]

"As regards the nuisance, that only occurs seriously when the tank is being cleared out?—I do not think there is more nuisance from the septic tank than from an ordinary settling tank to any great extent." [Tatton, 6733.]

The nuisance to which Mr. Tatton refers would not occur with a properly arranged septic tank, in which facilities are always provided for removing residual matter without emptying the tank.

"At present we have no open septic tanks dealing with ordinary domestic sewage; they are all closed, and from those there is no nuisance." [Tatton, 6735.]

"In the summer time, certainly, when you have the greatest objection from the smells, I should say that the covered septic tank was less objectionable than the open septic tank." [6740.]

"I need scarcely ask you, therefore, if you found any nuisance to arise from your septic tanks?—Practically none. I may say it is possible to stand immediately over the great evolution of gas and scarcely be conscious of anything. The marsh gas has a tendency to cause a certain tickling in the throat, but I think that is not at all serious. The only time that we are at all conscious of the presence of the septic tanks is on a very close, muggy day, when there is no air whatever." [Fowler, 8403.]

See also 4455, 5737, 6503, 6504, 6523 *et seq.*, 6545, 6936, 7707 *et seq.*

In this connection it is interesting to note the experience of Mr. Scott Moncrieff with his cultivation tanks:—

"It has been an invariable experience that at the end of about a fortnight we have been able to predict three days of a bad smell, from two to three days of a very offensive smell, and that has also invariably passed off." [Scott Moncrieff, 3383.]

The influence of trade wastes in suppressing smell was particularly referred to.

Mr. Fowler was asked with regard to the tar products present in the Manchester sewage:—

"Do they affect the septic tank at all, or do they enter it?—They enter it, and we can smell the tarry odour. My

SMELL FROM SEPTIC TANK—*continued.*

feeling about it is rather that they have acted to some extent as deodorants, and consequently we have had less troublo on the score of smell than we might otherwise have had." [Fowler, 5570.]

"Of course, we have a great many other things than pure sewage in what comes to our works, and it is quite possible that the intermixed trade effluents, and so on, may act to some extent as deodorants. The smell in our case, I think, is very slight." [8405.]

"It is very likely, I suppose, that trade refuse and sewage combined would produce much less smell than the domestic sewage; that seems to be the case at Leeds certainly?—It may be so, yes." [Tatton, 6739.]

"But Leeds sewage is diluted and mixed with trade effluents, and no doubt where strong domestic sewage is being treated greater nuisance may arise." [Harding, 7245.]

A question was also raised as to nuisance arising from the effluent after leaving the tanks:—

"A fresh septic tank liquid is not an unpleasant liquid." [Rideal, 4454.]

"With the closed septic tanks you are more apt to have a nuisance from the filters; as the septic effluent flows from the tanks it smells strongly sometimes. But the tank itself being closed up, no smell comes from that except through the outlet through which the water flows." [Tatton, 6604.]

Mr. Mawbey's experiments at Leicester in the irrigation of old pasture land with tank effluent received special attention from the Commissioners:—

"In my opinion you cannot treat septic effluent on grass land by broad irrigation without causing a serious nuisance." [Mawbey, 8188.]

But Mr. Mawbey also found "a very offensive smell" from the area to which the crude sewage was applied. [8083.]

"(Professor Ramsay): Would you describe the product of a septic tank as extremely offensive? Is that the normal action of a septic tank?—The ones I have seen, I think, are not what you might call offensivo. [8234.]

"Does it depend on the kind of refuse that you have that you are turning into the tank—ordinary domestic sewage and ordinary trade effluent?—I do not think one could

Smell from Septic Tank—*continued.*

describe the ordinary liquid of towns from the septic tank as always cxtremely offensive. [8234*.]

"(Sir Michael Foster): Colonel Harding's experience is there is occasionally a bad smell."

"(Colonel Harding): We have not found at Leeds any serious nuisance arise from septic tank effluents where septic conditions have fully developed?—(Mr. Mawbey): Wc have found the reverse. It has been extremely offensive, and more offensive when the septic conditions are ripe than it was even at the earlier stages." [8235.]

The reason for the striking contrast presented by Mr. Mawbey's experience at Leicester and his observations elsewhere is doubtless that suggested by Sir Michael Foster:—

"It rather seems to indicate that there was something in the nature of the Leicester sewage which led to these offensive smells."

Passing on from broad irrigation with septic effluents to their treatment in contact beds, Colonel Harding observed:—

"You suggest that using septic tank effluent upon a contact bed you would be less likely to find a nuisance arise than spreading it over a large area of land?—(Mr. Mawbey): Oh, yes, certainly, most emphatically; so that if you can get it straight from the septic tank on to a contact bed I do not think that there is very much fear of a nuisance." [8326.]

"You would not expect that if your septic effluent were thrown in a thin film over a large area of land there would be any serious nuisance produced?—Oh, no. As matter of fact, we have two half-acre beds of the size we expect eventually to use in daily use, and there is no difficulty whatever on that score." [Fowler, 8406.]

"Did any nuisance arise in connection with contact bed filtration?—Nono whatever. Even on digging deep into the beds which had been receiving Leeds sewage for long periods, there was no smell but that peculiar to garden soil." [Harding, 7062.]

The whole question of smell from septic tanks is well summed up by Mr. J. D. Watson in his Birmingham lecture, in which he said that

"At a great sewage works nuisance invariably followed pumping, churning, brushing and cleaning operations of

all kinds," but that "where the works were in a quiescent state there was almost an entire absence of smell."

GASES GENERATED IN SEPTIC TANK.

The gases generated in the septic tank have an interest apart from the question of their odorousness or otherwise.

It has been ascertained by several experimenters that these gases possess a high calorific value. The following is an abstract of the principal evidence as to their composition:—

> "Dr. Rideal made analyses of the gas from the tanks in 1896. . . . He found the percentage by volume to be carbonic acid 0·3 per cent. in the first case, and 0·6 per cent. in the second; * *organic matter* to be 20·3 and 24·4; hydrogen, 18·2 and 36·4. The gas found in the tank burns freely, and it has been estimated by Mr. Dibdin that it has half the value of coal gas of 16-candle power." [D. Cameron, 1885.]

These analyses are mentioned also in Dr. Rideal's evidence, in which the balance of the percentage in each case is given as nitrogen [4135].

> "Has any examination been made of the gases in your tank?—I have made several analyses. They are chiefly marsh gas." [Whittaker, 4804.]
>
> "Have you examined and analysed the gases, so as to form an opinion as to what those gases mostly are?—Yes, we found that they consisted of nearly 90 per cent. marsh gas. [Fowler, 5572.]
>
> "Which is inodorous?—Yes." [5573.]

In the following March Mr. Fowler was able to give a further analysis of the tank gases:—

> "We found by a somewhat rough analysis, by an ordinary laboratory gas analysis apparatus, that the mean of our results came to about 73 per cent. of marsh gas, 6 per cent. of carbon dioxide, and 5 per cent. of hydrogen, and the rest we put down to be nitrogen, 16 per cent." [8401.]

A question was raised by the Commissioners with respect to these gases, which does not appear to have been answered by any of the witnesses:—

> "In what way would the enclosing of the tank help you;

* Evidently printed in error for "marsh gas."—A. J. M.

Gases generated in Septic Tank—*continued.*

for if malodorous gases are produced by the putrefaction of matters in the tank, these malodorous gases cannot be confined indefinitely in the tank; they must escape somewhere?—That is a question that I could not answer." [Chatterton, 6546.]

The explanation is a simple one. The gases in question cannot be confined by such a material as concrete. They therefore diffuse freely through the arches into the soil, which constitutes an effective deodorant, if any such is needed. So rapidly does this diffusion take place that Messrs. Dibdin and Thudichum, who made an examination of the gases at Exeter, were unable to detect any pressure in the upper part of the tank, even with the most delicate gauges.

Coarse Beds.

Both the "cultivation tank" and the "septic tank" are avowedly designed as workshops for anaërobic bacteria. It has also been attempted to effect the preliminary treatment of sewage under aërobic conditions, by means of "coarse beds" or filters worked on the contact system, the first of which was laid down at Sutton, Surrey, in 1896, under the guidance of Mr. W. J. Dibdin, then Chemist to the London County Council, and a member of the Sutton Urban District Council.

The considerations which led Mr. Dibdin to adopt this method of dealing with solid matter are set out in his opening statement, in which, referring to the work done in the well-known "one-acre filter" at the Barking or Northern Outfall of the London main drainage, he says:—

"Summarising the result of the work accomplished on the one-acre fine-breeze bed between September, 1893, and November, 1896, it appears that 500,000,000 gallons of settled sewage were treated. Since the sewage which was passed on to the filter contained an average 7 grains of suspended matter per gallon, a quantity equal to 2,232 tons of sludge, of 90 per cent. moisture, had been entirely removed, the filtrates being practically free from suspended matter. Of the matter thus removed, about 110 tons were organic (estimated dry), the whole of which had been oxidised, whilst the sand amounted to about 40 tons, which, calculated

at 24 cwt. per cubic yard, would cover the filter to a depth of 0·267 inch if spread equally over its surface. Such sand, however, had been carried into the body of the bed, and after three years there was no sign of its presence, and no danger of choking has arisen from this cause. The organic matters in solution in the effluent absorbed on an average 3·5 grains per gallon of oxygen from permanganate in four hours, whilst the filtrate absorbed only 0·7 grain. The amount of oxidation effected, measured in this way, would require 90 tons of oxygen. The organic matter in solution completely removed, as determined by the difference between the loss on ignition of the solids in the crude settled sewage, and the filtrate, amounted to 250 tons, making, with the 110 tons of suspended organic matter, a total of 360 tons.

"These conclusions pointed most clearly and definitely to the greater question, viz., that if the organisms had been able to accomplish so much work on the finer solid matters in the sewage, why should they not be equally potent for the destruction of the larger particles which in the aggregate form what is known as 'sludge'? It was evident that if these coarser matters were placed upon the fine bed they would speedily accumulate on the surface and form a deposit of putrefying matter. They must be enabled to penetrate into the mass of the bed, and this could be accomplished by making the bed with coarse particles of coke, ballast, &c., the interstitial space between which would form channels through which the sewage would flow, carrying with it the suspended particles. When the bed was full these would settle on the fragment of coke immediately below them, or be attracted to the side of the nearest mass, and there be subjected to the action of the bacteria and other low forms of life, which would in due course ultimately effect their complete destruction.

"Whilst this could go on to a certain extent, it was also evident that, owing to the necessity for supplying the organisms with fresh oxygen from the air, the bed must be emptied periodically, and that this would have to be done before the whole of the work was accomplished; hence the necessity for the second, or fine bed, in which the work could be completed. These considerations led to the construction of the first coarse bacteria bed at Sutton, where the witness suggested it to the district council (of the

COARSE BEDS—*continued.*

> predeccssors of which body he was a member). The suggestion was taken up, and the bed brought into use on November 20th, 1896, and it has continued to give satisfactory results up to the present time. Further confirmatory experience has since been gained by the results of extended trials of the system at Leeds, Blackburn, Aylesbury and elsewhere." [*Interim Report*, vol. II., p. 115.]

Mr. Dibdin's views herein expressed are confirmed from a bacteriological standpoint by Dr. Sims Woodhead.

> "It is possible to get rid of almost the whole of the sludge; that is, all the organic sludge in a biological filter bed. Clay, sand, or anything of that kind cannot be dealt with in such a bed. That must be intercepted in some way; but organic matter in sewage should, in a properly constructed filter bed or a biological filter bed, be got rid of completely; because micro-organisms have the power of digesting practically all kinds of organic matter if you can only get the right organisms, and obtain the proper conditions in which these organisms may work. [Woodhead, 2818.]
>
> "Would you tell us how the sludge difficulty is affected? —By the organisms digesting and getting into solution the organic sludgc. Even the cellulose gives way. It is converted into more soluble substance. The various insoluble forms are gradually acted upon; the more soluble forms are acted upon moro rapidly, and sugars, which are comparatively easily dealt with, are produced. In addition there are, in sewage, the undigested nitrogenous substances, the substanccs from meat, and so on; but these are all digested in time; in fact, some of them very rapidly." [2819.]

Before sending sewage on to a coarse bed it was customary to get out as much of the solid matter as possible by means of fine screcns, but the smaller particles, which it was impossible to remove in this way, were, as indicated by Mr. Dibdin, carried into the filtcr and deposited on the surface of the matcrial. A good dcal of this, as already mentioned, was gradually liquefied by the bacteria present, but it was generally found that in coursc of time the interstices filled up, reducing the "water capacity" of the bed to a scrious cxtent. A part of the capacity thus lost could often be made good by giving the filter a prolonged rest; but such recovery was in most cases partial and temporary only.

COARSE BEDS—*continued.*

The treatment of crude sewage in coarse beds received an exhaustive trial at Manchester at the hands of the three experts, Mr. Baldwin Latham, Dr. Percy F. Frankland and Professor W. H. Perkin, jun., appointed by the Rivers Committee of the City Council to advise them as to the disposal of their sewage. The conclusion arrived at from these experiments is thus referred to:—

"(Colonel Harding): Now I believe they (the experts) have made experiments in double contact filtration of crude and partially settled sewage at Davyhulme, and they came to the conclusion that it was not practicable to deal with crude sewage, or partially settled sewage, upon contact beds unless the bulk of the larger part of the suspended solids had been first removed?—(Mr. Fowler): Certainly. [5476.]

"The result as to the quality of the filtrates which they obtained was good, but the capacity of the filters was too easily reduced?—That was their opinion." [5477.]

Similar results were obtained at Leeds.

"(The Earl of Iddesleigh): We now come to the important question of maintenance of capacity of the beds. In your opinion, can contact beds be used indefinitely?—(Colonel Harding): No. Our experieuce was that in dealing with crude sewage, and even with screened and partially settled sewage, there was a steady loss of capacity. The process was found to give good results as to effluents, but the real difficulty is that a working capacity of the beds cannot be maintained, except at an impracticably low scale of work. It must be noted that the difficulty arose almost exclusively in the first or rough beds. The fine beds gave us no trouble." [7063.]

"Notwithstanding these accumulations and consequent loss of capacity, you have no doubt that there was a large digestion by the rough bed of the suspended solids which passed into it?—Certainly. A large part was digested. It is difficult to get at any reliable estimate of the sludge digested by the beds. Taking No. 1 rough bed, the total volume dealt with, from October, 1897, to October, 1899, was 38 million gallons; and if the average of suspended solids kept back by the bed is taken at 33 grains, then

Coarse Beds—*continued.*

178,000 lbs. of dry solids, or 1,780,000 lbs. of sludge (90 per cent. water), has been left on that bed, or, at 10 lbs. per gallon, 178,000 gallons. As the final accumulation in the bed was 56,000, it would seem that this bed had digested 68 per cent. The quantity is no doubt less, as the upper sludge left on the bed contains only 85 per cent. water. On the other hand, the reduction of capacity is partly due to breaking up of the material of the bed, and some matters at first in solution are thrown into suspension and retained. As a rough estimate, 60 to 70 per cent. may be taken as a fair approximation of the sludge digested by this bed." [7066.]

Col. Harding took care to guard against the impression that these figures could be taken as absolute.

"Is it possible to get definite data as regards this digestion?—I think the answer given to the question to which you refer is based upon insufficient data, namely, one experiment, to warrant anything like definite conclusions. [7193.]

"Are any experiments being made of the kind?—No; it seems to be very difficult to ascertain the amount of digestion of suspended solids by contact beds. [7194.]

"But you believe that digestion does take place?—Oh, I think undoubtedly digestion does take place; but I am afraid it may be exaggeration to say that it extends from 60 per cent. to 70 per cent. I think, probably, it would be found to be, judging from what has been done by septic tanks not quite so large, between 50 and 60 probably." [7195.]

The experience gained at Manchester and Leeds is typical of that obtained at other places where the treatment of crude sewage upon coarse beds has been attempted. At Sutton, the birthplace of tho coarse bed, the sewage is now settled before being passed on to it. That even sedimentation is not in all cases a sufficient preparation is shown by the experience of a country town, where the upper beds, although dealing only with settled sewage, clogged to an alarming extent, and, on the writer's advice, septic tanks wero ultimately laid down.

The inadvisability of entrusting to coarse beds the duty of

Coarse Beds—*continued.*
dealing with suspended solids is now generally recognised, and contact beds are rarely laid down without the protection of septic or sedimentation tanks.

It has already been mentioned that where the purification of sewage is effected in two stages, the interception and liquefaction of the solids is almost invariably the first step. There is nothing, however, more characteristic of the wholo question of sewage treatment than its steady refusal to be bound by rules. Hardly has a principle becomo well established, and taken its place as a canon to govern practice, when some new fact is brought to light which, if it does not actually annul it, at least greatly narrows its application. Thus the microbe, which not so long since was condemned and sentenced as the enemy of mankind, has now been pardoned, and received into favour as a valued servant. Decomposition, at one time strenuously avoided, is now recognised as the most potent, in fact, the only, method whereby sewage can be rendered innocuous.

When the cardinal principles which governed the purification of sewage were so ruthlessly uprooted, it was not to be hoped that more details of practice would be respected. Accordingly, in one of the most recent developments of sewage treatment the elimination of suspended solids has had to yield its precedence to the purification of the liquid. This new and interesting departure was first tried at Leeds, and the filter employed for the purpose is accordingly known as "the Leeds filter." Although in the process in question filtration takes the first place, it is not a "preliminary treatment" in the sense in which the term is generally understood, so it will be convenient to let the Leeds filter stand over until other filters come to be dealt with.

CHAPTER IX.

COMPARATIVE VALUE OF MODES OF PRELIMINARY TREATMENT.

THIS question, like that as to the need for preliminary treatment, has its theoretical and its practical side, and it will be convenient to deal first with the former.

There is no point, probably, on which a keener controversy has raged than as to whether the preliminary treatment should be conducted on aërobic or anaërobic lines.

THE SCIENTIFIC JUSTIFICATION OF ANAËROBIC TREATMENT.

The main scientific justification of anaërobic treatment lies in the fact that a large proportion of the solid matter present in sewage is made up of paper, vegetable débris, and, where the roads are paved with wood, small particles of this material. In all these cellulose, or woody fibre, forms an important constituent, and there is good ground for believing that cellulose is only liquefied under anaërobic conditions.

> "Do I understand that the destruction of bodies, such as paper and cellulose, &c., only occurs in the depths?—So far as really accurate observations on the destruction of cellulose go, that appears to be the case. The cellulose-destroying organisms have been isolated of late, and found to be anaërobes. They carry on their work of destroying vegetable fibre and vegetable cell-walls, dead leaves, and so forth in the mud, in pools, and in marshes, in ponds, &c., and it is owing to their action that quantities of marsh gas are given off at various times. And in late researches in Neva mud a cellulose-destroying organism has been isolated, which, provided it is cultivated in the absence of air, fixes itself upon pieces of paper, causes the fibres slowly to swell and dissolve, and, in fact, destroys this fibre, destroys cellulose, and there can be no doubt that substances like paper are destroyed in that manner in the

SCIENTIFIC JUSTIFICATION OF ANAËROBIC TREATMENT—*continued.*

soil or in domestic sewage. This occurs only in the depths, but there have been cases described where actions of this sort can go on nearer the supply of air—say, at the surface of a liquid—provided some other organisms can protect the anaërobic one from the action of oxygen." [Ward, 2543.]

"A large proportion of the sewage must consist of cellulose or allied forms; there must be a considerable quantity of material of that kind in the sewage?—I should think so. [2610.]

"And a good deal of the so-called suspended matter which is not of an inorganic nature is probably more or less allied to cellulose, cellulose being so very insoluble?—Yes; materials like paper and wood, and any vegetable refuse, would, of course, contain a great deal—I mean comminuted substances, like straw, parts of vegetables that have passed undigested through animals, and such-like bodies, would contain large quantities of cellulose." [2611.]

"But did I understand you to say that all the cellulose-destroying organisms were always those which acted under anaërobic conditions?—Yes; I think I am right in saying they are all anaërobic. [2613.] See 2543.

"You do not know at present of organisms which can destroy cellulose, and especially which would destroy simple suspended articles of cellulose and the like, under aërobic conditions?—I can recall none. No, they are all anaërobic that have been worked out; all the cases that I am acquainted with concern anaërobic forms. [2614.]

"Then might we infer from that that in the disposal of sewage it is most desirable that, at all events, a part of the process should be of an anaërobic kind?—Yes; otherwise I do not see how much of the solid matter would be got rid of." [2615.]

"Then it is not necessary to provide for the destruction of sewage in special anaërobic conditions?—I should say not. Certainly as regards that part of the destruction of these solid bodies it could go on, provided the other organisms are present, symbiotically helping them." [2623.]

"And Colonel Ducat says he takes the crude sewage with only large masses screened off and puts it on the top of the filter, and that as it passes through the filter the whole of

Scientific Justification of Anaërobic Treatment—*continued.*

the solid matter is destroyed, including in that case a very large quantity of cellulose ?—I know of no aërobic organisms that would do that." [2625.]

"The greater bulk of the material of the sewage which has to be changed is non-nitrogenous—cellulose, or the like ?—Yes ; non-nitrogenous. [Woodhead, 2888.]

"And that cellulose, of course, is not converted into ammonia, it is converted into carbonic dioxide ?—And carburetted hydrogen. [2889.]

"That takes place by means of organisms which act aërobically or anaërobically ? — Anaërobically, probably. [2890, 2891.]

"Exclusively anaërobically ?—Well, I should not like to say exclusively ; but all the experience that I have is that a great part of this is formed during the anaërobic stage of the breaking-down process. Of course, you know at Exeter they have such a quantity of this gas that it may be burnt off from the anaërobic tank. [2892.]

"You have no knowledge of aërobic organisms which can break up cellulose and like material ?—No. [2893.]

"Nevertheless, in the system which was described by Colonel Ducat, there, under conditions which were obviously aërobic, he states most distinctly that large masses of the sewage, obviously cellulose in character, or of like nature, do disappear through the action of the filter ?—Yes. [2894.]

"And, therefore, we may presume, must have been destroyed by aërobic organisms ?—Yes ; but it would not be in the form of marsh gas in that case. I think it is very probable, as I said before, that aërobic organisms can do almost anything. [2895.]

"Then it is probable that there are aërobic organisms which can dispose of—let me use a general word—dispose of cellulose and allied matters ?—Well, I should say it is possible, distinctly. [2896.]

"But you do not know of any ?—I do not know of any, because I have not done any experiments in connection with that. All the cellulose experiments I have notes of so far are anaërobic, and resulted in the formation of marsh gas." [2897.]

Although it is not absolutely denied that cellulose may be liquefied aërobically, it will be noted that the view spontaneously

Scientific Justification of Anaërobic Treatment—*continued.*
taken by both witnesses was that anaërobic treatment is necessary, and that where they subsequently admitted that the work might be done aërobically, their evidence to this effect hardly went beyond giving aërobic treatment the benefit of the doubt which was raised by the questions put to them.

It has, however, been shown (pp. 120, 121) that a considerable amount of liquefaction of sewage solids can be effected in a coarse bed under what appear to be aërobic conditions. It is open to doubt whether the work which is done in such a bed is, in reality, wholly aërobic. The question was raised by Sir Richard Thorne in his examination of Dr. Sims Woodhead.

> "When you were referring to Mr. Dibdin's filter, you spoke of aërobic changes taking place on the surface of the filter, and anaërobic change taking place in the depth?—Taking place in the depth, yes." [2837.]
>
> "But I think you have not had much experience of the cases where double filtration has been in operation to crude sewage?—Yes, I have. I think the preliminary filter in most of these cases is nothing more than an anaërobic chamber." [2935.]
>
> "But I was rather anxious to get at this point: whether, if the first filter is to be considered as working anaërobically, it would not be possible, in your opinion, to work it continuously instead of intermittently; one does not see the necessity for aëration?—I think it is far better to work it continuously." [2942.]

From the witness's point of view, therefore, Mr. Scott Moncrieff's "cultivation" tank is preferable to a coarse bed worked on the contact system.

Professor Frankland points out that—

> "The supply of sewage to a single bacteria bed, as was done at first, fails to secure such separation of the anaërobic and aërobic, and is a fatal objection to the 'single contact' system.
>
> "The mere supply of air to a bacterial bed does not ensure aërobic conditions, the latter being dependent also on the amount and nature of the organic matter present in the sewage supplied.
>
> "The separation of the aërobic and anaërobic processes would be best secured by the application of the sewage to a number of beds placed in series. . . .
>
> "A further separation of anaërobic and aërobic processes

SCIENTIFIC JUSTIFICATION OF ANAËROBIC TREATMENT—*continued.*

> is effected by the use of the 'septic tank' or 'cesspool,' in which anaërobic processes can alone take place." [*Interim Report*, vol. II., p. 530.]

The arguments in favour of a preliminary anaërobic treatment are largely based on the considerations set forth in the last few pages. It was hardly to be expected, however, that those which have been most freely used by some of its opponents to discredit the anaërobic processes would be repeated before the Commissioners, consisting as they did of appeals to prejudice, based on the alleged identity of anaërobic decomposition with putrefaction, and of a septic tank with a cesspool.

That anaërobic decomposition is not necessarily putrefactive, nor putrefactive changes exclusively anaërobic, is clearly shown by the evidence of Professor Ward (pp. 66, 67). But, even if it were otherwise, and the whole of the work which is done in a septic tank or cultivation tank were putrefactive, the fact would not justify the methods of those who ascribe to anaërobic decomposition, *carried out under control*, those grave dangers which arise from putrefaction *when it goes on in the wrong place.*

If some prefer to speak of a septic tank as a "cesspool," no serious objection could be raised to their doing so, were it not for the attempt which has too often been deliberately made to play upon the fears of the ignorant by adroit references to the mischief which has been caused by leaky or improperly ventilated cesspools in basements, or in the neighbourhood of wells for the supply of drinking water. Happily both modes of preliminary treatment have now been long enough before the public to be judged on their merits, and local authorities are no longer deluged as they used to be with appeals to prejudice or panic.

If there are still any who doubt the value of putrefaction as a means of disposing of dead organic matter, they would do well to read the eloquent presidential address delivered by the late Dr. Angus Smith to the Congress of the Sanitary Institute, held at Glasgow in 1883, in which, after referring to the large amount of decomposing matter in the Clyde, he went on to say:—

> "If nature had contrived no method of destroying such seeds of death, populations such as this is would never have grown up. And what is the method? That method is, first, putrefaction; at least, I know of none other, except the concluding portion of the work, viz., thorough oxidation." [Transactions San. Inst., vol. V., p. 275.]

Suspended Matter.

Turning now to the practical side of the question: the primary object of preliminary treatment being to obtain an effluent which is free from solid matter, the first point to be considered in a comparison of the various forms of such treatment is their efficiency in this respect, as judged by the amount of suspended matter which the effluents contain. Mere screening, as already mentioned (p. 79), leaves the amount of suspended matter practically unchanged.

Suspended Matter in Precipitation Effluents.

Chemical precipitation is highly efficient in this respect; a good effluent, like that at Kingston, containing as little as 1·4 parts per 100,000.

The subject is dealt with by Mr. Douglas Archibald in a paper read in 1903 before the Sanitary Institute at Bradford:—

> "In proportion as chemicals are disused, and septic action or mere sedimentation relied on, so, apart from the proportion of insoluble chemicals deposited, more suspended solids, both mineral and organic, are ejected in the tank effluent. Where heavy charges of precipitants are used, as at Kingston-on-Thames, the tank effluent contains no more than 1 grain of suspended matter. At other places, where smaller doses are used, such as Chorley, Richmond, &c., the effluent contains from 3 to 5 grains. At London, where less than 5 grains of chemicals are added, the effluent from the tanks is said to contain about 8 grains per gallon." [Journal of San. Inst., vol. XXIV., p. 332.]

In his examination of Mr. Fowler at Manchester, Colonel Harding appears to regard 4 grains of suspended matter per gallon (5·71 parts per 100,000) as a low figure for a precipitation effluent. [5467.]

The effluent from lime precipitation at Leeds contains 10 grains per gallon of suspended solids (14·3 parts per 100,000). [Harding, 7063.]

At Salford,

> "in the average composition of the tank effluent the suspended matter varies from 2 grains to 5 grains to the gallon (2·86 to 7·14 parts per 100,000), and oftener it is 2 grains (2·86) or 3 grains (4·29) than 5 grains (7·14), 5 grains being rather an exceptional quantity. [Carter Bell, 15502.]

The tanks are followed by a roughing filter, which

"takes out about 75 per cent. of the suspended matter." [15509.]

The suspended solids, however, show a rapid increase where chemicals are stinted, or the tanks are not carefully looked after.

The cultivation tank, properly handled, should also be capable of doing good work in the removal of solid matter.

SUSPENDED MATTER IN SEPTIC TANK EFFLUENTS.

The effluents from septic tanks generally contain appreciable quantities of suspended matter: the amounts found by various witnesses are given in the following table:—

Place.	Parts per 100,000.	Witness.	Answer.
——	4·57	Stoddart	Int. Rep. Vol. 11, p. 291.
Manchester	under 10·0 to 28·6	Fowler	5532
Accrington	17·8	Whittaker	5721
Leeds	11·4 to 14·3	Harding	7051
*Birmingham	24·4	Watson	14510
Sheffield	about 15·7	Haworth	14818
*Burnley	about 13	Ross	15345
Oldham..........	5·71 to 27 Ave. about 14·3	Valentine	15592-3

* The tanks hold only 8 hours' flow.

Mr. Fowler, referring to the suspended matter given off by a septic tank at Manchester, said:—

"It was working altogether 14 months, and I should say, from the observations we made (I have an average we worked out during that time), it worked out at something like 7 grains (10 parts per 100,000); but in the earlier period for the first four months very, very little, and then it averaged up to 20 grains (28·6 parts). [5532.]

"But the 20 grains would scarcely be the average condition?—Oh, no. [5533.]

"That would be a sort of maximum condition?—That was the maximum, yes. [5534.]

"Do you think the 7 grains you spoke of could be taken as an average of the later period?—No, at the last it was over 7 grains; the last few months. [5535.]

"What would it be?—I should say something like 15 (21·4)." [5536.]

"At Leeds, with septic tank effluent, there would be generally only 8 or 10 grains (11·4 or 14·3 parts per 100,000) of suspended solids to be dealt with." [Harding, 7057.]

In a subsequent table Colonel Harding gives 13 grains (18·6 parts) as the average in one set of experiments (7063), and later on he adds:—

"It is fair to say that our trials were made with the effluents from septic tanks which had been long at work without emptying, and which, in consequence, were passing out over 15 grains per gallon (21·4 parts per 100,000) of suspended solids. In a septic tank, working with a 24-hour flow, there should not be more than 8 grains per gallon of suspended solids (11·4)." [7069.]

Suspended Matter in Coarse-bed Effluents.

The following are instances of suspended solids in coarse-bed effluents:—

Place.	Parts per 100,000.	Witness.	——
Sutton	4·51	Dibdin	Int. Rep. Vol. II., p. 131
Leeds	15·1	,,	,, 133
Aylesbury	11·1	,,	,, 135
Blackburn	6·0	,,	,, ,,
Sutton (granite filter)..	14·4	,,	,, 136
,, (chalk)	trace	,,	,, ,,
,, (slate)	,,	,,	,, ,,
Leeds	16·4	Harding	,, Ans. 7037
,, ...	18·0	,,	,, ,,
,, ...	19·6	,,	,, ,,
Sheffield	about 4·3 to 5·7	Haworth	Third Rep. Vol. II., 14824

Suspended Matter—*continued.*

The comparative freedom of the best precipitation effluents from suspended solids, and the presence of the latter in considerable quantities in those from certain septic tanks, has been made a good deal of by the advocates of chemical treatment. Colonel Harding, who can hardly be said to fall within this category, frankly recognises the merits of precipitation in this respect.

> "Where cost is not a fatal objection, or where there are facilities for economically disposing of sludge, chemical settlement offers this advantage, that the withdrawal of suspended solids can be more thorough than by the septic tank action, and the less suspended solids in an effluent, the easier the filtration. As yet, no satisfactory means has been found to prevent suspended solids coming out in the septic tank effluent to the extent of from 20 to 35 per cent. of those originally in the sewage." [Harding, 7261.]

At Birmingham, Mr. Watson mentioned the amount of suspended solids in an effluent from precipitation as 16·3 parts per 100.000, as against 24·5 in that from the septic tanks; but it should be remembered that the latter held only eight-hours' flow.

The value of the comparisons which have been made is, however, greatly reduced by the fact that they have generally lain between the effluents, on the one hand, from processes which, like that at Kingston, represent the acme of chemical precipitation, and those, on the other hand, from septic tanks which have either been experimental, or have been laid down when the septic tank was still in its infancy, and when, therefore, little or no experience was available for guidance in its design.

With tanks of more recent construction, the amount of suspended solids in the effluent shows a marked reduction as compared with the effluents from earlier tanks. [See Fowler, 8390.] At Leeds, for instance, the average rate for the first half-year was 8·3 parts per 100,000, and although, as mentioned above, a considerable increase was shown in the returns for succeeding half-years, there is no doubt that this could have been prevented by removing deposit periodically from the tank, so as to keep the conditions approximately constant. The case is an instructive one, showing as it does the need for attention to this point. An analysis made by Messrs. Tatlock and Thomson in April, 1904, of the effluent from septic tanks at Barrhead, which had been in continuous operation for the past six years, and from which no deposit had ever been removed, gives 7·97

SUSPENDED MATTER—*continued.*

parts per 100,000; while Mr. Naylor's analysis of a sample of tank effluent taken last February from the more modern installation at Yeovil, dealing with the exceptionally foul sewage of that town, shows two parts only. These fignres compare very favourably with the results from chemical precipitation as ordinarily carried out; bnt it must be borne in mind that some of them are based on single samples, so can only be regarded as an indication of what can be done in the way of obtaining a solid-free effluent.

More conclusive testimony on this point is furnished by Dr. George Reid, County Medical Officer for Staffordshire, in his Report presented to the Sanitary Committee on 2nd July, 1904. In this Report he sets forth the results of an important series of experiments carried on at Hanley during the previous eighteen months by himself and Messrs. Willcox & Raikes, Civil Engineers, of Birmingham. Seven sets of analyses are given, the amount of suspended solids in the tank effluent, in parts per 100,000, being respectively as follows: 4·4, 3·7, 3·2, 3·7, 3·3, 5·2, 7·6. The average of the whole series was 4·4 parts, that for the sewage being 62·9. That these results are not the best which can be obtained from a septic tank under the best conditions is shown by tho following extract from the Report:—

> "It may be well to point out, however, that the routine working of the works generally interfered somewhat with the regularity with which the detritus tank was emptied, with the result that a larger proportion of the mineral-suspended solids in the sewage passed into the septic tank than otherwise would have been the case, thus curtailing its effective capacity more rapidly than is usual. The effect of this, no doubt, was that the septic tank effluent was not the outcome of twenty-four hours' septic action throughout the whole period of the experiment, and, at times, probably an increase in the suspended solids passing from the septic tank to the filters resulted from this unavoidable shortening of the septic period." [Hanley Report, pp. 4, 5.]

Mr. Stoddart was examined on the subject by Colonel Harding:—

> "Can you in the case of a septic tank get an effluent with so few solids in suspension as five parts per hundred thousand?—Oh, yes. [5058.]
>
> "No difficulty with that?—No difficulty at all." [5059.]

In comparing the suspended matter in chemical and septic effluents, it should be borne in mind that the latter is less clogging than the former, and that "it does not hold the water to the same extent." [Fowler, 8411.] Colonel Harding in his reply on this point says, "Another advantage (of septic tanks) is that the suspended solids passing to the filter are in a finely-divided condition, and less likely to choke the filters." [7261.]

Destruction of Sewage Solids.

Next in importance to the question of freedom of the effluent from suspended particles is that of the efficiency of the process in disposing of solid matter.

In chemical precipitation all that is attempted is to arrest the solids. Their subsequent disposal formed the subject of a question put by the Chairman of the Commission to Mr. Santo Crimp:—

> "Have you any remarks that you could make to us about the disposal of the sludge?—That, of course, is the most troublesome thing that we have to do with in connection with sewage-disposal works, where the suspended matters are removed from the sewage to begin with. Of course, where there is a large area of land, which is of a suitable character and remote from houses, the sewage can be applied as it comes from the sewers without creating offence; but that has been done for a great number of years, at the Beddington Sewage Farm for example, where no attempt is made to remove the bulk of the suspended matter. But, even there, the time may come when they will have to remove the suspended matter, on account of the great growth of population which is going on at Croydon and the districts which drain to that farm. There are, of course, many other cases, but where the sludge is taken out by means of chemicals, and the population is at all large—and by large I would almost go down to about 10,000 people as the limit, or even lower than that; I think it would be safer to go to 5,000 as the limit, the downward limit—undoubtedly the filter-press should be adopted for dealing with the sludge. The usual practice where the filter-press is not employed is to run the sludge into what some people call lagoons, which is a very misleading term. The beds are formed, as a rule, of town ashes, or any porous material that can be got, and the sludge is run into these beds in the hope that it will dry down; but

DESTRUCTION OF SEWAGE SOLIDS—*continued.*

if the quantity produced weekly is at all large, that system results in a great nuisance being produced, then undoubtedly the proper way of dealing with sludge is to press it by means of filter-presses. That was done, I believe, at Aylesbury, in the very first instance. I cannot give you the date when the filter-press was first employed there, but I believe that was the first case. I believo the Croydon Rural Sewage Works, at Merton, on which I was engaged, to which I referred in regard to artificial filters, was the second caso; and I believe Wimbledon was the third case in which filter-presses were employed, and that is as recently as 1882, I think, at Wimbledon; but now hardly any sewage work is considered complete unless filter-presses are employed for the purpose of dealing with the sludge. The operation of the press is, briefly, to reduce five tons of wot, sloppy, stinking sludge to one ton of cake, which can be handled, carted, and disposed of as soon as produced. Thero are cases, of coursc, where the larger limit of population is reached—London, for example—where it has been found undoubtedly that the most economical method is to pump it into steamers and take it away to sea. I advised the Salford Corporation to adopt the same course, and they adopted my advice, and they take their sludge now down the Manchester Ship Canal, and dischargo it into the soa beyond Liverpool. The Manchester works were brought into operation about the same time as the Salford works, and they adopted filter-presses there; but having seen the result of steamship carriage, they have now adopted at Manchester thc same method of disposing of the sludge as at Salford; they have it shipped down the canal and disposed of in the sea. So that where the quantities of sludge produced are very large indeed, no doubt that is the most satisfactory way of disposing of it. It has a vory low manurial value even after being pressed." [1625.]

In all the bacterial processes tho sludge is, as far as possible, destroyed, leaving only a residuum, the volume of which por million gallons of sewago is variously cstimated, but which is in no case so great as to occasion serious trouble or oxpense in its disposal. The residuum from a cultivation tank or septic tank may readily be forced out by the pressure of tho liquid up to a level approaching that of the surfaco of the latter, and is geno-

DESTRUCTION OF SEWAGE SOLIDS—*continued.*

rally dug into land. At Manchester, however, the plan originally adopted was to remove sludge from the tanks in an imperfectly digested state and take it out to sea by steamer. Latterly, means have been provided for drawing off the mineralised residuum without disturbing the sludge in the body of the tank.

An important point in favour of this residuum, as compared with the sludge obtained by precipitation, is its relative inoffensiveness, pointed out by Colonel Harding in his answer already quoted (p. 90).

In practice, given tanks of ample size, it is possible to carry the decomposition of the organic matter to such a stage that very little change will subsequently take place, and to draw it off in such quantities and under such conditions as to give rise to no offence.

It is difficult to get any reliable information upon which to base a comparison of the amount of liquefaction effected by a coarse bed with that which takes place in a septic tank. Colonel Harding, referring to the experimental work done at Leeds, said :—

> "The data we have would seem to show that as good results were obtained by aërobic as by anaërobic change. This experiment upon this rough bed referred to in my answer, you see, gives results which are somewhat over those which have been obtained by anaërobic action in septic tanks." [7197.]

The writer has heard it gravely urged in favour of coarse beds, as compared with septic tanks, that deposit would accumulate in the latter and would have to be removed; but it does not require much reflection to show that the intractable residuum which accumulates in a septic tank is not likely to be digested any more easily in a bacteria bed. Its removal from the one, moreover, is a matter of the greatest ease, while in the other case it is impossible to get rid of it, short of washing the body of the material. It is this consideration probably more than any other which has led to the general adoption of tanks rather than beds for the initial treatment of sewage.

Comparison of Effluents.

The various preliminary processes may also be compared in respect of the effluents which they yield, the latter being judged either by the results of chemical analysis or by their amenability to filtration.

Comparisons between the effluents from chemical precipitation and those from septic tanks were drawn by several witnesses:—

> "Have you formed any opinion as to whether the anaërobic action of the septic tank facilitates the subsequent filtration, apart from the reduction in suspended matter to be dealt with?—I have not the least doubt that it greatly assists nitrification. [Fowler, 8407.]
>
> "You think, therefore, that if you took septic tank effluent on the one hand, and you took effluent from chemical precipitation or natural sedimentation on the other, and the other cases had the same amount of suspended solids to deal with, you would get better results from the septic tank effluent than from the others?—As far as our experience goes, it is undoubted. [8408.]
>
> "What do you base your conclusion upon; because, if I remember, the only experiments you had made with chemical effluent were by the Roscoe filters. It is on that experience?—Not only these, but our experiments with settled sewage. Before we took septic tanks we worked with raw sewage and settled sewage, with beds which afterwards took septic tank effluent, and we never got a non-putrefactive effluent with one contact under these circumstances, and by no means always with two; whereas now, with septic tank effluent, we get constantly non-putrefactive effluents with one contact, and effluents of the very highest degree of purity with $1\frac{1}{2}$ contacts." [8409.]

The last answer is important, as showing that the work of the septic tank goes beyond the removal of solid matter.

COMPARISON OF EFFLUENTS—*continued.*

Typical analyses were produced by Mr. Stenhouse of the effluents obtained by precipitation with alumino-ferric and by bacterial treatment at Rochdale :—

Grains per Gallon.	Alumino ferric.		Bacterial.		
	Raw sewage.	Tank effluent.	Raw sewage.	After septic tank.	After bacteria beds.
Total solid matters (dried 100 C.)	60·8	46·6	60·8	45·5	51·0
Matters in suspension	21·0	5·5	21·0	8·0	5·3
Combined chlorine	7·7	6·2	7·7	7·5	7·2
Alkalinity expressed as lime.	8·1	5·5	8·1	7·7	1·7
Oxygen absorbed in 4 hrs. ..	5·80	2·85	5·80	3·51	1·05
Free or saline ammonia	1·84	1·81	1·84	1·57	0·04
Albuminoid ammonia	0·76	0·33	0·76	0·49	0·12
Nitrogen as nitrates........	—	—	—	—	0·99
Percentage of purification as judged by oxygen results.	—	52 p.c.	—	39·5 p.c.	82 p.c.

A very interesting footnote is appended to this table.

"NOTE.—Since the above evidence was given it has been found that a quantity of water from the river Roche was gaining access to the main outfall sewer, and consequently diluting the sewage during the period over which the analyses were made.

This influx of comparatively pure water having been stopped, the analytical results since obtained during ten weeks of summer weather show that the raw sewage averages 40 per cent. fouler than the above tables indicate. The bacterial treatment, however, continues to be as efficient as before, but the effluent from the ordinary tank treatment is much worse." [Stenhouse, 12371.]

Another instance of the same kind was adduced by Dr. Wilkinson, medical officer for Oldham :—

"What system is it?—Precipitation, followed by the bacteria beds. It gave a good effluent, an effluent coming below the standard required; but it was found, after a time,

COMPARISON OF EFFLUENTS—*continued.*

that the effluents were obtained whether we used precipitants or whether we did not. [15586.]

"Then do I understand you have abandoned precipitants?—Then we abandoned precipitants." [15587.]

Dr. Reid, in his Hanley report, already referred to, gives some septic tank results, which compare favourably with the best from chemical precipitation :—

> "It will be seen that treatment in the 'septic' tank effected a purification of 64 per cent. and 62 per cent. in the organic ammonia and oxygen absorbed figures respectively." (Hanley Report, p. 8.)

Before leaving the subject of comparative results, it is only right to point out that the Chorley works, in the district of the Ribble Joint Committee, using precipitation and filtration through polarite, have for the three years ending 6th March, 1901, turned out an effluent which is claimed by Mr. Alderman Hibbert, chairman of the Sewage Works Committee, to be the best in the watershed.

No analyses are given of the effluents from cultivation tanks; but the essential difference between these and septic tanks is mentioned by Mr. Scott Moncrieff as consisting in what he calls the "zonal" character of the former, reference to which has already been made (p. 83). Later on, Mr. Scott Moncrieff, being asked to define the difference in principle between the two tanks, said :—

> "While in the case of the Exeter installation Mr. Cameron has an empty tank, I have a tank full of flints. [3310.]
>
> "(Colonel Harding): I am quite aware that there are differences in details, but the main principle in it is the same, is it not?—Well, that embodies a very important difference in principle; it means the difference between a nomadic and a fixed population, which is a difference in principle." [3311.]

The distinction thus drawn is a sound one, and the question has been raised by other writers whether it is not better to provide anchorages for colonies of bacteria throughout the body of the liquid. The present writer is not aware of any reliable experiments which have been carried on for the purpose of clearing up this point, and until it is demonstrated that better results are to be obtained by filling up a tank with flints or

similar material, the choice of method will probably be influenced by the fact that it is cheaper to provide a given space in a clear tank than in the interstices of a mass of stones, and easier to remove undigested matter from the former than from the latter.

Smell from Effluents.

Regard must sometimes be paid to the condition of the effluent in point of smell. This has been referred to chiefly in connection with the septic tank; but for the purpose of a fair comparison with other processes, it is necessary to know whether the preparation for filtration is equally complete in all cases, or whether the comparative freedom from smell of some of the effluents considered is merely due to the breaking down of the organic matter having been left to be accomplished by the filters.

Fall Absorbed.

It is seldom that an engineer has a free hand in the design of a sewage purification plant, and of all the limitations under which he has to work, the most common and the most serious is that due to lack of fall. A certain amount of fall is absolutely necessary for filters, so that, where it is scanty, as little as possible should be expended on the preliminary treatment. It is therefore an important advantage of the cultivation tank and the septic tank that neither absorbs any fall.

> "(Colonel Harding): Now, from an engineering point of view, the relative value of the septic arrangement which you have been experimenting with at Manchester—and the double contact beds, would offer these distinctions, would they not?—that in the case of the septic arrangement you could work more on one level; in the case of double contact beds you must necessarily have the first raised above the second?—Yes; that is so. [Latham, 4638.]
>
> "And therefore, possibly, pumping arrangements would be involved in the second case which would not be necessary in the first?—That is so." [4639.]
>
> "From the engineering point of view there is this advantage in the septic tank, that there is no loss of head, the effluent going out at the same level that the sewage comes in." [Harding, 7261.]

Relative Cost of Preliminary Processes.

It would be interesting, especially to local authorities, to compare the various preliminary processes in respect of cost, but on this point there is little information to be gleaned from the evidence. A question on the subject was put by Colonel Harding to Mr. Fowler:

> "And in view of the cost of chemical precipitation, and the vast amount of sludge produced, they did not propose to adopt chemical precipitation as a first process antecedent to filtration?—No." [5478.]

The advantage of bacterial processes over precipitation in this respect is generally conceded, but some diversity of opinion has been manifested as to the relative cost of the former processes:—

> "The expense of making a large area of covered septic tanks would probably be double that of a corresponding area of filters to deal with the same quantity." [Latham, 4640.]

This is evidently an offhand opinion, for an examination of the initial outlay on a large number of installations shows that the cost of the filters is, as a rule, something like double that of the septic tanks.

The advantage of tanks in point of cost is recognised by Colonel Harding:—

> "So far as the treatment of crude sewage upon contact beds is concerned, I am quite satisfied that it would be impracticable for us to do it, because of the very large and very costly area of the beds which would be required. [7201.]
>
> "Would introducing septic tanks reduce the area of those beds very materially?—Yes, the reduction of capacity would probably be considerably less. [7202.]
>
> "But including the area of the septic tanks and the area of the beds together, is the total area of land covered reduced?—I have not calculated out what the relative area would be, but I should think it probably would be considerably less with septic tanks, and I think the cost of septic tanks would be distinctly less than the cost of the filters. [7203.]

Relative Cost of Preliminary Processes—*continued.*

"Would you take into account also the necessity of repairing the filters if they are used for intermittent filtration, in comparison with the cost of filtration in connection with septic tanks?—Repairing filters? [7204.]

"I mean renewing the material, and so on?—The cost of renewing material or sorting material would obviously be very much greater if you are dealing with crude sewage than with septic tank effluent, because choking would be very much more frequent, and sorting would be very much more frequently necessary." [7205.]

The witness was, however, of opinion that "the Leeds bed arrangement will be less costly than septic tanks followed by Whittaker beds." [7396.]

CHAPTER X.

FINAL TREATMENT.

The main object in view in the final treatment of sewage is the oxidation of the ammonia and organic compounds resulting from the preliminary process to which it has been subjected. The oxidation of the ammonia produces successively nitrous and nitric acids, which unite with the lime, soda, and other bases present to form nitrites and nitrates of the latter. This series of changes is known collectively as "nitrification." The carbon on oxidation yields carbonic acid gas, which likewise combines with the bases in the effluent, forming carbonates.

Nitrification.

The process of nitrification and the conditions under which it takes place are described at considerable length in the evidence.

> "(Professor Foster): Then, speaking of nitrogenous matters, the change which takes place in proper treatment of sewage is, first, the bringing of the nitrogenous material into the condition of ammonia, and then the conversion of that ammonia into nitrates?—(Dr. Sims Woodhead): Yes, I think so from my experience." [2870.]
>
> " . . . . In manure we should have large quantities of ammonia being given off under the action of certain bacteria, which are particularly apt to destroy urea. We should also have at the surface, ammonia given off by the destruction of more complex nitrogenous bodies. Then it is found that—especially at the surface, but, under certain circumstances, it is suggested even lower down—this ammonia is gradually converted by two stages into nitric acid, which in the presence of salts like calcium or magnesium would form nitrates; and lastly, we can now no longer doubt that there are certain forms which undo this work, break down the nitrates and the nitrites,

NITRIFICATION—*continued.*

and carry them down past the stage of ammonia, until even free nitrogen is evolved; and, of course, that is the most complete form of this destruction that we can figure. There are numbers of urea bacteria now described, and there is no doubt that the conversion of urea into ammonium carbonate is a very common event in all such heaps as the above, and takes place very quickly under the action of these bacteria. Nitrification, the gradual formation of nitric acid from this ammonia, the gradual oxidising of it and building it up into nitrites and nitrates, has now been definitely demonstrated as the act of two distinct bacteria. They have been so carefully worked out that we can no longer doubt that the principal steps even in detail are now known. And lastly, under certain circumstances, these nitrates can be attacked by other organisms, other bacteria, and the work undone again. Indeed, one of the most interesting problems in theoretical agriculture is to see how we can prevent this undoing of that good work by the second series of bacteria, and which undoubtedly goes on in ordinary manure heaps. Denitrification has now become one of the most important questions concerned in this destruction of organic bodies." [Ward, 2540.]

"The final end of all these changes being, as I think you suggested in the beginning of your remarks, the production of nitrates as suitable material for the growth of plants, is the antecedent phase to the nitrate always an ammonia phase?—Yes, so far as I know, always ammonia; I know no cases where it has been worked out for anything but ammonia. [2598.]

"So that, regarding nitrates as tho desirable goal of the changes, one ought to strive for the reduction of the material to the ammonia stage as an antecedent?—Yes. [2599.]

"To the action of these nitrifying agents?—Yes." [2600.]

In the consideration of the work done in bacterial filters, attention is frequently concentrated on tho nitrification effected, to the neglect of the carbon oxidation and other changes which go on. A broader view is taken by Dr. Fowler, in a lecture which he delivered at the University of Manchester on 24th March, 1904:—

"Changes in Bacterial Beds or Filters.—Here tho changes are even more complox. As far as our present knowledge

NITRIFICATION—*continued.*

goes we have to distinguish at least three classes of change, *physical*, *chemical*, and *biological*. Among the latter may be distinguished changes due to *bacterial* or plant life, and changes due to animal life.

"In a new, unripened filter, the *physical* effect is first apparent. The matters in emulsion, and in many cases in actual solution, are retained by the medium by a process of *physical absorption*, akin to the condensation of carbonic acid gas on moist glass wool observed by Bunsen. Purely *chemical* oxidation of certain compounds may take place owing to condensed oxygen, *e.g.*, ferrous compounds such as ferrous sulphide are oxidised, also sulphuretted hydrogen to sulphuric acid and certain leuco bases to the corresponding dyes.

"Hypochlorites are oxidised to chlorates, and thus a means is found for purifying hospital sewage sterilised with chloride of lime. Whereas phenol will, when present in large quantities, inhibit the action of the bacterial filters, these are practically unaffected by the presence of reasonable amounts of chloride of lime. These apparently purely physical and chemical changes require further study.

"The bacterial changes are chiefly those concerned in the gradual conversion of ammonia into nitric acid, the process known as *nitrification*, and the subsequent oxidation of organic matter by means of the nitrate formed. But purely carbon oxidation changes must go on, *e.g.*, the breaking down of dextrine and sugar, &c., and, no doubt, the processes started in the septic tank are carried on and complete themselves in the primary bed or in the upper layers of a continuous filter." [Lecture, pp. 13, 14.]

"The experiments that we have carried out indicate that a large number of the organisms found in sewage exert a distinct influence in bringing about nitrification. That it is not confined apparently to the described nitrifying organisms, but that any organisms which grow rapidly and break up sewage material have the power of inducing or commencing, as it were, this process of nitrification, if a sufficient quantity of oxygen is always present, is evident." [Woodhead, 2809.]

"I have already mentioned that the changes in the natural purification of sewage lead more to the production of nitrites than of nitrates. For the group of transforma-

NITRIFICATION—*continued.*

tions working to this end I use the term 'nitrosification,' implying the production of nitrites *by partial oxidation*, as distinguished from the special reduction of nitrates called 'denitrification,' which was proved by Gayon and Dupetit to be a 'fermentation involving direct burning up of the organic carbon at the expense of the oxygen of a nitrate.' Nitrosification is not nearly so delicate a process or so difficult to initiate or control as nitrification, which it seems to invariably precede. It occurs best in the presence of diffused light and of a moderate amount of air, and is quite consistent with the growth of large numbers of green or brown algæ which are at the same time engaged in reducing any nitrates present." [Rideal, 4155.]

The nitrification which takes place in the soil is thus referred to:—

"Have you examined the surface of soils, the ground below the surface of soils, for nitrate or for evidence of nitrification? Have you examined the soils somewhat below the surface for evidence of nitrification or for nitrate bacteria? —No; the nitrate bacteria which I cultivated were taken from the surface of the soil. [Dr. Frankland, 10035.]

"Are they more numerous on the surface than further down?—Mr. Warington, you may remember, made very extended experiments on that subject, and he found them, I forget now to what depth; I think it was 6 feet or 12 feet. He published two series of results. In the first set he said they did not extend beyond 18 inches or 3 feet, or something of that kind; and then he tried another method of cultivation, using sulphate of lime, by which the nitrifying bacteria are apparently very much stimulated, with a result that he found them to a very considerably greater depth when he used that method of cultivation; but I think there can be no doubt that nitrification goes on to a considerable depth in the soil. [10036.]

"And in a peaty soil do you know what takes place pretty well?—Oh, I think in a peaty soil nitrification very rarely takes place. Nearly all the waters which are derived from peaty areas are practically free from nitrates altogether. [10037.]

"But containing nitrogen in other forms of combination? —Oh, yes; both ammonia and organic nitrogen. Of course,

for one thing the acidity of the water prohibits nitrification. Nitrifying bacteria are very sensitive to acid." [10038.]

Hindrances to Nitrification.

Mr. Scott Moncrieff's evidence as to the inhibiting effect of an excess of free ammonia has already been quoted [p. 105]. Some further information on this point is given by Dr. Rideal :—

"Is there any chance of the products of the fermentations bringing the process to an end?—As regards mass action, and the hindering of a reaction by the presence of the product of an enzyme change, with the possibility of attaining a point of equilibrium between a direct and inverse change, the work of Hill (J. C. S., August, 1898) seems to be decisive. . . . . In a solution so dilute as a sewage the influence of the products would hardly be felt, so that the enzyme changes would proceed to completion. Still, the action is more energetic when the products are removed as formed, and the bacteria are supplied with fresh food. In nitrification the solution must not be too strong nor too alkaline. Warington found that a 12 per cent. solution of urine was the highest strength nitrifiable, and that the maximum alkalinity corresponded to 36·8 parts per 100,000 of nitrogen as ammonium carbonate, equal to 44·6 parts of ammonia. These are strengths which only under special circumstances would be approached in sewage. In the runnings from urinals, stables, &c., dilution would be necessary." [4140.]

"Several observers have proved the inhibiting action of carbonic acid on bacteria, especially those which are oxidising; therefore it is important, when the third or oxidising stage is reached, that the carbonic acid should be removed by free circulation of air as soon as formed, or the failure of nitrification noticed in so many of these filters will follow." [Rideal on Sewage and Sewage Purification, p. 191.]

"From experiments which I have made on mixtures of sewage and sea-water, and the slowness with which nitrification occurs in some cases, I am inclined to think that the presence of chlorides prevents the formation of nitrates—I am inclined to think so." [Letts, 8624.]

It would follow from this that where nitrification is aimed at it may be inadvisable to use large quantities of sea-water for flushing the sewers. [See also Fowler, 14377.]

CHAPTER XI.

BACTERIAL FILTERS.

With two exceptions the final treatment of sewage is always effected in a filter of one kind or another. The first alternative to filters is the "nitrifying channel" introduced by Mr. Scott Moncrieff, but now abandoned by him in favour of filters. The other is the "biological tank" of the Oxygen Sewage Purification Company.

There are many varieties of bacterial filters, but they may be classified, roughly, under three heads:—

(1) Land filters, consisting of naturally porous soil.
(2) Artificial filters, formed from land of less suitable quality, and worked as land.
(3) Artificial filters, formed with special materials, and worked in a special manner.

1. Land filters have already been fully described in connection with intermittent downward filtration.

Artificial Filters, formed from Land.

2. Artificial filters, formed from land, are described by several witnesses:—

"If, on the other hand, you can do as we have done at Wimbledon, increase the porosity of the top soil to a depth of something like fifteen inches by the admixture of ashes, we put on an enormous amount of screened town ashes there, and we have got now about fifteen to eighteen inches of this very porous top soil, and as a result we can go up to 7,500 gallons per acre on our Wimbledon soil at the present moment. That I consider is about as far as we shall be likely to get, because we have to cease putting our ashes on the farm at Wimbledon, and burn our ashes in the refuse destructor; but I have no doubt whatever that if we did

continue the system, and got a greater depth of this porous medium on the top, we should be able to put on a larger proportion per acre." [Crimp, 1578.]

"Attempts have been made to lighten our heavy clays in Derbyshire by digging in engine ashes; Draycott is an example of this. Here a large sum of money was spent in digging in ashes, but the only result has been that the sewage goes through the clay at certain parts, and at other parts it does not go through at all. The result is, that where the ashes have been dug in, those parts take the bulk of the sewage; and where it does go through little purification, if any, is effected." [Barwise, 4022.]

"(Major-General Carey): Of course, that soil can be improved, as was suggested, I think, in one of your answers, by mixing; either digging it out, burning it, and replacing it, or mixing it with cinders?—Yes, that is so; but as it is it is wholly unsuited for sewage purification." [Dr. Wilson, 6140.]

"(Mr. Power): Have you had any experience in the West Riding of land made suitable, even when it was unsuitable; do you know anything as to its cost?—Yes, sir; I have particulars in one instance. In the case of Ossett the cost was £140 an acre, and what was done in that case was to remove 18 inches of soil from the surface of the land and to take out the next 18 inches, burn it, and replace it mixed up with the upper 18 inches." [6142.]

"That £140 includes the burning and replacing?—Yes, that was the contract. The engineer himself said it was very low, and his estimate was £180 per acre." [6145.]

"(Colonel Harding): It would be interesting for you to give us the result of this improvement of the land that was made at Ossett?—I am sorry to say the result has been very bad, and apparently the land in that case is relapsing into its original condition. [6147.]

"Consolidating?—Consolidating again. But the circumstances are very peculiar there, because the sewage is highly acid sewage, sir. In the Ossett district there is a great deal of carbonising and dyeing; very much of the acid effluent is discharged into the sewers, and the sewage itself is almost always strongly acid in reaction, and no doubt the acid, which is chiefly sulphuric acid, would act upon the clay and tend to bring it back to its original condition. [6148.]

Artificial Filters, formed from Land—*continued.*

"And act also on the bacterial life by which the changes are brought about in the soil?—Exactly; the result is that the effect of the land treatment upon the tank effluent is very slight, indeed chiefly in the way of removing suspended matters. [6149.]

"(Mr. Power): Your experience is that the land quickly reverts to the state of the land in its original condition?—I am only speaking of the experience of this one place, where the sewage is peculiar. [6150.]

"(Chairman): Is that the only case in which you have had experience?—Of that, my Lord. [6151.]

"Is it the only case where the land has been broken up and made into a sort of artificial filter bed that you know of?—Where it has been removed and burned. [6152.]

"You may call that a sort of turning the land into an artificial filter?—It has been done on a small scale in several other farms; for instance, at Featherstone, where the soil is of the same nature as this, it was done in the large beds, which were practically formed into bacteria beds. [6153.]

"Well, and did they succeed?—They produced a very good effluent and they did not seem to revert to the original state. The burned ballast still apparently remains. [6154.]

"And they are in work still?—They are at work still. [6155.]

"And how long have they been going on?—They must have been going on now for two years. [6156.]

"(Mr. Power): And the particular land that did revert; what lapse of time was there between its burning and its becoming to be decidedly unsatisfactory again?—It began to revert to its original condition, I should say approximately, about two years from the time it was dealt with. [6157.]

"(Mr. Killick): No cinders or refuse were added to the burned ballast?—Not in that case. [6158.]

"(Major-General Carey): Of course, it does materially affect the question whether the ballast is well burned?—Oh, it must make all the difference. [6159.]

"In the one case you get a very hard filter material and in the other case a filter material which is ready to revert to its original condition?—In the one case it would approximate to the form of broken bricks." [6160.]

Artificial Filters, formed from Land—*continued.*

"Going back to land, have you any experience of artificial preparation of land by the addition of chalk or cinders, or anything of that sort?—Yes, I know that if you have properly screened town refuse, not town refuse that has been burned in a destructor, not that at all, but where you have the place properly scavenged, and the refuse brought into heaps, sifted, burned and sifted again, I say that you can increase the purifying capacity of a clay soil or an indifferent soil very largely indeed—probably more than double it. By putting this carefully on the surface you raise the whole surface to start with, and undoubtedly it has a most beneficial effect. [Chatterton, 6462.]

"And would that beneficial effect be lasting, do you consider, or would the land tend to revert?—It depends on what the soil is. I am talking now of putting it on to a fairly stiff clay and keeping on until you build the land up, but it is a process that can only be done by a thoroughly experienced man who will see that he burns his stuff properly, and does not put on any garbage or muck or anything like that. It is a process that must be done carefully. Also on the same principle an ordinary domestic sewage sludge which has been pressed, when it comes out of the press is in a very useless condition, but if it is thoroughly dried and then powdered up, that also has a considerable beneficial effect on the land provided it has not been done too much. You could not put nearly so much of that on the land as you could of well sifted house refuse. [6463.]

"Do you mean when you say put it on to the land, simply lay it over the surface?—Lay it over the surface. [6464.]

"Not dig it in?—Dig it in slightly. [6465.]

"And that is an operation that would have to be repeated, I suppose?—It is continuously repeated and it is most beneficial; you can grow excellent crops of rye grass; altogether the appearance of the farm would be a great deal better; but also it is a thing that must be done by a man who is experienced and thoroughly understands it." [6466.]

"Have you any experience of attempts towards artificially prepared land by the addition of chalk or cinders or other material, or digging out the top soil and burning it and replacing it?—At Eccles they have done a certain amount in that direction; they have dug ashpit refuse into the land—

Artificial Filters, formed from Land—*continued.*

it is a heavy loam—with beneficial results, and I know at Wimbledon they have turned the clay there into burnt ballast. Of course you can do that; you can burn the clay, but it is an expensive process; that can be done. [Tatton, 6606.]

"I only want to ask you where you have actually seen and known the process?—Yes, quite so. [6607.]

"But you have known it?—Yes, I have. [6608.]

"That, I suppose, increases the capacity of the land for filtration?—It does, somewhat, no doubt. I have had no experience as to digging it in in heavy clay. I should doubt whether that would be a success permanently." [6609.]

Wholly Artificial Filters.

3. Of wholly artificial filters there are several kinds, distinguished rather by variations in the mode of working than by radical differences in their composition or structure.

Before passing on to describe them it may be noted that the word "filter," used in this connection, has been objected to as a misnomer, the term "bacteria bed" being proposed to take its place.

"What do you mean by a mechanical filter?—Simply a system in which by putting obstacles in the way of particular matter you prevent its passing along with the fluid. In the case of these bacterial beds we are not dealing with matter by mere mechanical straining out. I think the term 'filter' is a bad one as applied to these beds; we have rather, practically, an accumulation of micro-organisms into a small space, which do a certain amount of work on the material that is kept back for them by the mechanical part of the filter. [Woodhead, 2842.]

"Yes; but what mechanical filter that would deserve the name of a filter acts in any other way?—Well, they are numerous. For instance, the numerous filters on the market recommended for the filtration of water; of course, many of these do not deserve the name of filters, and a large number of filters are nothing but mechanical filters, and though they keep back large particles they let small particles through." [2843.]

"Would you kindly explain why you use the expres-

Wholly Artificial Filters—*continued.*

sion 'contact bed' in preference to 'filter'?—Because it is not filtration in any sense of the word. Filtering is a straining process which takes place from the surface downwards. The contact beds fill up from the bottom upwards, and simply lie in contact; there is no straining and no removing in that sense as filtering." [Latham, 4527.]

While the principle of "one word, one meaning" is undoubtedly a sound one, it is permissible to point out that, if this principle is violated by the use of the word "filter" in the sense referred to, extenuating circumstances can be pleaded. If the word is taken in its narrowest sense as implying a fine strainer, it must be admitted that a bacterial filter does not fall within its meaning; but if a filter is regarded in its broader sense as a mass of material through which water is passed for the purpose of purification, a bacteria bed may fairly be held to come under the definition. In the absence, therefore, of a more appropriate and equally convenient term, the writer proposes to adhere to the word "filter."

The third class of bacterial filters, comprising what may be called artificial filters proper, may be grouped in two sub-classes, the first comprising those filters which are filled and emptied alternately, the object being to hold the effluent in contact with the filtering material, and the second those through which the liquid flows without being brought to rest therein. The filters included in the first sub-division are known as "contact beds," and the others will be referred to here as "flow filters."

The latter group may be sub-divided still further into "streaming filters," through which the liquid is allowed to flow freely, and "trickling filters," through which it percolates in thin films in contact with the air.

CHAPTER XII.

CONTACT BEDS.

The first filters on the contact system were the "one acre" coke bed laid down in 1893 by the Metropolitan Main Drainage Committee at the Barking outfall, and two small beds constructed in 1895, at the suggestion of Sir Henry Roscoe, by the Rivers Committee of the Manchester City Council at their sewage disposal works at Davyhulme. The principles underlying this system are set forth by Mr. Dibdin as follows:—

"General Observations on Filters.

"The action of a filter is twofold: (1) It separates mechanically all gross particles of suspended matter, and renders the effluent clear and bright; (2) it effects the oxidation of organic matters, both those in suspension and those in solution, through the agency of living organisms. It is the preliminary establishment and subsequent cultivation of these organisms which is to be aimed at in the scientific process of purification by filtration.

"The ordinary putrefactive and other similar organisms commence the work by breaking down the organic compounds and converting them to less complex forms, principally water, carbonic acid, and ammonia; the nitrifying organism then acts upon the ammonia, the nitrogen being converted into nitric acid. For this process to go on, three conditions are essential: Firstly, the organisms must be supplied with plenty of air; secondly, there must be present a base, such as lime, with which the nitric acid can combine; and thirdly, the biological action must take place in the dark, *i.e.*, in the body of the filter, and not in the water exposed to the light above the filtering material. Filtration on biological lines of sewage or other foul water containing in

General Observations on Filters—*continued.*

solution but little freo oxygen and a large quantity of oxidizable organic matter therefore means :—

1. That the filter, by cautious increments in the quantity of effluent, which in itself contains the necessary organisms, must be gradually brought to a state of high efficiency. This condition will be shown by the existence in the filtrate of a constantly increasing proportion of nitric acid.
2. That the contact of the micro-organisms with the effluent to be purified must be effected by leaving such effluent at rest in the filter for a groater or less time according to the degree of purification required, the process being analogous to that of fermentation. The system employed in many places is to run the water straight through the filter and thus allow insufficient time for the work, with the result that the filtrate is soon in an unsatisfactory condition.
3. That after each quantity of effluent has been dealt with, the micro-organisms must be supplied with air, which is readily effected by emptying the filter from below, whereby air is drawn into the interstices. The filter must stand empty for an hour or more previous to another filling, and a longer period of aeration, say twenty-four hours, must be allowed every seven or eight days.

"The life of a coke breeze filter worked in this manner is practically without a limit.

"From the general results obtained by these several trials under various actual working conditions, it is apparent that there is no difficulty in obtaining any desired degree of purification by means of a system of filtration conducted on biological principles. If a highor degree of purity be required than that indicated by the foregoing, it can be obtained by an augmentation of the filtering appliances at a comparatively small cost, as, whero clay is obtainable, tho mothod of construction employed in making the new burnt ballast filter bed at Sutton may be adopted, viz., by simply digging out the clay to form a pit about three feet deep, and filling it up with the same clay after burning, and thus a cheap and efficient filter bed is obtained; the cost of the large filtor bed at Sutton, having an area of 4,454 square feet, or rather

General Observations on Filters—*continued.*

more than one-tenth of an acre, being less than £100, including all charges.

"By such a system the necessity for costly farms is entirely obviated. The results are completely under control, and the filters can be arranged to suit all requirements it is possible to contemplate." (Report by Mr. W. J. Dibdin, F.I.C., F.C.S., Chemist to the London County Council, on the experiments on the filtration of sewage effluent during the years 1892-3-4-5.) [*Interim Report*, vol. II., p. 127.]

It may be noted that the mode of construction proposed by Mr. Dibdin has not found favour with the Local Government Board, and that the general practice is to provide the filters with floors and walls of brickwork or concrete.

Method of working Contact Beds.

The method of working contact beds is thus described by Mr. Dibdin:—

"*Time of contact.* This point constitutes the main difference between the system now known as the 'Sutton' and the method of intermittent downward filtration. It was found necessary for the sewage to be subjected to the action of microbes, under proper conditions, for a certain period of time; if this were not allowed, the purification was incomplete; when it was greatly exceeded, the aeration, and consequent recuperation, of the bed was affected disadvantageously. For this reason the bacteria beds are locked, and the sewage kept in them for a period of about two hours; the effluent being then allowed to escape, the undestroyed portion of the organic matter held in the empty bed is vigorously attacked by the organisms under the most favourable circumstances of combined dampness and air supply, and the bed is thus prepared for a further charge. The necessity for the locking has been proved by numerous experiments, from which also the most suitable average time limit has been arrived at." [2176.]

The mode of working originally adopted by Mr. Cameron at Exeter, while in the main the same as that described by Mr. Dibdin, differed from it in that the "period of contact," instead of being fixed at two hours, varied with the flow, each filter being held full during the time required to fill the next, which, of course, was dependent on the flow at the time. The result,

METHOD OF WORKING CONTACT BEDS—*continued.*

speaking generally, was that a strong dry-weather flow sewage received a long contact, and a weaker wet-weather sewage a shorter one, the ratio between the periods of contact and those of aeration and draining being the same in both cases. In later septic tank installations a fixed period of contact has generally been adopted. Further information on the subject is afforded by the following evidence:—

> "Have they formed any definito opinion as to tho best length of time for contact with the filter?—Well, the result seems to be that they can afford to put on four fillings in the twenty-four hours, whereas we only put on three. [Roscoe, 3774.]
>
> "Quite so; but in doing that do they reduee the time of standing empty, or do they reduce the time of standing full?—They reduce the time of standing empty; they reduce the time of aeration. [3775.]
>
> "Then they do not reduce the time of eontact with the sewage filter?—No; it was the time of aeration which they reduced. [3776.]
>
> "Then have they been able to come to any definite conclusion as to the best time of contact? Have they varied their experience?—That I do not undertake to say; I do not really know. As far as my experiments are eoncerned, I found that the best result was, when they were resting full, 20 per cent., and when they were aerating, 60 per cent. That is what I found to answer best; but that as far as the contact was eoncerned, one hour's eontaet was sufficient. [3777.]
>
> "Then I must take it, Sir Henry, that you have no personal experience of experiments of longer and shorter contact?—No; I have made the experiments which I have stated here, namely, that we found the best thing we could do was to aerate for 60 per eent., and allow it to rest full for 20 per cent.; but, as I have said, one hour's contact gave us purification, so that we were probably in excess of the time of resting; and as it appears from the experiments which have been subsequently made that they were able to put on four fillings, while wo only worked with three. [3778.]
>
> "Reducing only the period of aeration?—Yes. [3779.]
>
> "(Professor Foster): But I think you said just now it was taken out of the time of aeration, and did not affeet the

Method of Working Contact Beds—*continued.*

time of contact?—Yes; the contact is the same, and the time of aeration, as I think I said, was diminished. [3780.]

"Might I just put in this question? Have you made any observation there in which you allowed the contact to be less than usual, and found that accompanied by inferiority in your filtrate?—We found that one hour's contact was sufficient; that the difference between one hour's contact and two hours' contact was inappreciable. [3781.]

"Have you tried half-an-hour or three-quarters of an hour? The filtrate is as good after one hour as it is after two hours?—Yes." [3782.]

"In all cases where domestic sewage is treated you would allow the four hours' rest after the filter was empty?—As nearly as possible. [Dibdin, 3896.]

"And two hours full when the filter was charged?—Yes. [3897.]

"Which is the more important, rest in the filter or rest after it is empty for aeration?—Rest after it is empty, because if the effluent from the coarse bed is not quite up to the standard, the fine bed will act as a safeguard, and that will be all right." [3898.]

"You say, 'it is essential also that after having been in contact the bed should be effectually drained and allowed time for aeration.' What time do you consider essential?—Well, what we are proposing to do, in the case of Manchester, is to get the sewage on to a bed in half an hour, let it remain in contact two hours, get it off again as quickly as we can, and allow it to aerate them; so we ought to get them filled and emptied in six hours, four times in the twenty-four hours. [Latham, 4692.]

"That is not four hours' rest?—No. [4693.]

"That does not allow four hours' rest?—No, it is three hours practically we allow them rest. That would be the maximum that we should be doing. [4694.]

"Or the minimum period of rest?—That would be the average period of rest during the twenty-four hours. At one period of the day, possibly when the sewage is strongest, the time would probably be altered somewhat, so as to give a little longer contact and a little longer period of rest; whereas in the early hours of the morning and in the night

METHOD OF WORKING CONTACT BEDS—*continued.*

time, when there is dilute sewage coming down, the times might be shortened." [4695.]

"The two filters at Kingston are about 1-200th of an acre each in area, and have been worked regularly since May, 1898, on the intermittent principle, viz. :—

hrs.	*min.*	
0	20	filling
2	25	standing
0	45	emptying
0	30	standing empty
4	0	

i.e., a total of four hours, or three fillings in twelve hours. They have hitherto been worked only in the day hours." [Sillar, *Interim Report*, vol. II., p. 299.]

"Did you try the value of different periods of contact?—Yes. Mr. Dibdin told us when we started work in 1897 that he had found two hours the best term for the beds to stand full. We tried shorter periods with inferior results, and found no appreciable advantage in increasing the period to four hours. It would seem that the supply of oxygen is absorbed in the two hours' contact, and if so, no benefit can be gained by keeping the sewage longer in the bed. The condition would tend to change from aërobic to anaërobic. Our experience, therefore, confirms Mr. Dibdin's." [Harding, 7053.]

"It appears that the period of rest is of more consequence than the period of contact, and that in most cases it is not advantageous for the latter to exceed one hour." [Fowler, *Interim Report*, vol. II., p. 468.]

"(General Carey): How are the beds worked?—We fill them three times a day. It takes about an hour to charge them. We have held them up full for one hour; for a short period we held them up two hours, with a very slightly improved effect, and it takes about an hour to discharge, and the remainder of the eight hours the beds remain resting empty." [Haworth, 14785.]

Cf. 3891 *et seq.*

While under ordinary conditions no great benefit is experienced from keeping the filters full more than one or two hours, an

Method of Working Contact Beds—*continued.*

opinion is expressed by some of the witnesses that an undue prolongation of the contact is distinctly harmful :—

"During the night, the flow being small, the filter takes a long time to fill, and a long time standing full : a condition which does not help matters, a condition which is not favourable to good working." [D. Cameron, 1878.]

"I do not wish to speak to you much about the filters, because you say that is not so much your province. But I understood you to say that for the filters to remain full for any length of time or beyond a certain time was not good for them ?—That is so. [2011.]

"That is to say, I suppose, there is a particular length of time during which they should be full or during which the materials should stay, the fluid should stay, in the filter ?—Yes. [2012.]

"If it is less than that—I mean if the fluid were run through too quickly the change would not take place, and if the fluid remains in the filter too long the change is not relatively so great ?—The result is not so great ; that is to say, so much is this the case that we have now devised a time arrangement for discharging the filters. With the new apparatus, when a filter fills it diverts the sewage to the filter to be filled, and remains itself full until a set time, an hour, an hour and a quarter, or whatever time may be fixed for it, and then discharges itself. There is nothing to be gained by letting the filter stand full more than an hour with our sewage." [2013.] See 7051 (p. 161). See also p. 222.

Mr. Fowler, however, gives some important evidence showing that for new and immature beds a prolonged contact is desirable :—

"Half-acre beds, which after several weeks' working failed to give a non-putrefactive effluent when only filled six times a week, two hours' contact being allowed, immediately gave non-putrefactive effluent when the period of contact was increased to twelve hours. With Manchester sewage, therefore, the best method of starting new beds appears to be to fill not more than once a day, giving at least twelve hours' contact, this period of contact being gradually reduced as the beds become more mature. With beds which

have been in use for several years, the total period of filling, standing full, and emptying need not exceed two hours." [14377.]

Rate of Filling and Emptying Beds.

The witnesses who were examined as to the rate of filling the beds seem to agree that a rapid filling is desirable :—

"I find it is essential that the bed should fill quickly, so as to retain the air within the porous material. If the bed is filled very slowly indeed, an anaërobic organism develops instead of the aërobic.

"It is essential also that after having been in contact, the bed should be effectually drained and allowed time for aeration." [Latham, 4505, p. 271.]

"Did you fill the beds slowly or quickly?—After various experiments we settled to filling in one hour or less. It seems desirable to fill as rapidly as practicable, and the speed need only be limited by the question of distribution. If you fill slowly, the lower portion has had sufficient contact before the top of the bed is reached; and if also you empty slowly, then the lower portion of the beds is waterlogged much longer than the upper, and it is impossible for it to be effectively aerated." [Harding, 7051.]

"You told us that you found it well to fill the beds as fast as consistent with effective distribution. What about the emptying?—We found that one hour for filling and one for emptying were convenient periods. No material inconvenience arises from emptying fast, while slow emptying reduced the period of aeration, and especially so for the bottom of the bed. It should be added that when the main flow has ceased, the bed continues to trickle for hours and days. The spongy matter which forms on the surfaces of the material gives up its water slowly, and it is during the time of trickling that the very best samples are obtained. At first, especially with rapid emptying, the flow is turbid and unsatisfactory owing, no doubt, to insufficient aeration in the lower parts of the bed and in the channels and pipes, and also to accumulation of solid matter in these." [7054.]

The question of rate of emptying is also dealt with on p. 224.

Modes of Distribution.

The modes of distribution are thus described :—

"The best method of distributing the raw sewage over these beds is, in the light of our present knowledge, by means of cast-iron troughs of square section laid about 1 foot apart, and regulated by screws at the end, in order to secure the water flowing over the sides, through file notches, regularly throughout their length. In order to secure each trough having an equal rate of feed, a method of regulating the flow of sewage into them should be employed, otherwise some of the troughs will be passing more sewage than others. Wooden troughs have been tried at Sutton, but the warping action under the rays of the sun is so considerable as to largely diminish their usefulness. In the original 'bacteria tank,' however, no such precautions were used, the sewage being run straight on to the top of the burnt ballast." [Dibdin, Purification of Sewage and Water, p. 130.]

"What system of distribution did you adopt?—In our first pair of beds we began by an elaborate system of troughs filled with holes, but we found the troughs constantly silting up with sludge, and the holes very soon stopped up. In the later beds we fed the sewage on to one end of the beds in a thin stream over a lip the full width of the bed. After a few days the coke under the lip was choked on the surface, and then the flow spread over it further, until after some weeks or months it passed almost to the far end of the bed before it could get down. When the bed became pooled or flooded we were obliged to fork the surface, or even to remove the upper surface. On the whole, we found it the most convenient plan to provide channels in the material itself, and from time to time to turn them over, and so vary their position." [Harding, 7052.]

"(Major-General Carey): How is the tank effluent distributed on the filters in Manchester?—At present we find that it distributes itself quite well by the semi-circular weir which we have devised. I may say that the engineer, Mr. Wilkinson, has spent a good deal of timo in devising a special apparatus for distributing the tank effluent on to these beds, and it has been his endeavour to have as few penstocks to open as possible, and with that object in view

he has admitted the effluent over a semi-circular cill or weir. This forms a rim on a shallow reservoir, which is connected with the supply channel by two penstocks, so that on opening these penstocks the tank effluent fills this shallow reservoir and spreads in a thin sheet over this semi-circular cill, and so across the bed; and at present this is all we do. We find it simply spreads over the bed in a thin sheet, and finds its way in. I am not at all sure that we may not find it better to cut grips in the surface, and these grips would become clogged with the suspended matter, and the intervening spaces will readily take the air when the bed is empty; but at present we are simply putting it on in a thin sheet over the surface, and it seems to work very well." [Fowler, 8534.]

"(Major-General Carey): And how long does it take to fill the bed under those circumstances?—We can fill it in half-an-hour." [8537.]

At Exeter, Mr. Cameron distributed the tank effluent over the filters by means of lines of stoneware channels, sunk flush with the filtering material. With this arrangement the surface of the filters may be at the same level as the sewage in the septic tanks, so that no fall need be lost.

Automatic Working.

It is obvious that the success of the contact system depends, in great measure, on the precision or otherwise with which tho beds are worked. The earlier installations were in many cases regarded as experimental, and were kept under careful observation for the purpose of recording the results. Under these circumstances, it was easy to have the valves opened and closed by hand. In practical working, however, the expense of keeping a man constantly on the spot for this purpose would be a serious matter, for small places at all events; and at best it is difficult to ensure the regular fulfilment of a task the times for the performance of which cannot be prescribed in advance, but have necessarily to depend on the varying flow of the sewage. It soon became evident, therefore, that if the contact system was to havc a fair chance of success, some scheme of automatic control must be devised. To Mr. Cameron belongs the credit for the introduction of automatic working:—

"That was another object I had in view when I designed

AUTOMATIC WORKING—*continued.*

> these works, to make them independent of manual attention; works which could be left day and night to work continuously without any attention." [D. Cameron, 1874.]

Mr. Cameron goes on to describe the automatic apparatus which he used in the first installation at Exeter.

> "What would you say were the special advantages of a biological filter?—The special advantages, I think, are that it may be made to work automatically; these filters are not dependent in any way upon attention, that is, if they are properly worked." [Woodhead, 2818.]

The apparatus used to control the working of contact beds received but little attention at the hands of the Commissioners; but Mr. Fowler, in an appendix to his evidence, refers briefly to the experimental automatic gear which was used in the closed septic tank installation at Manchester. He mentions that, "when all the working parts are in good condition, the apparatus is capable of working smoothly and well," but goes on to say:—

> "The corrosive action of the septic tank effluent tends, however, to loosen any screws or nuts exposed to it, and the connecting pipes also become in time coated with deposit, so that frequent attention is necessary from these causes."

The weak points developed by the Manchester experiment were eliminated in the permanent design of the apparatus referred to, and the writer understands that the set which was shortly afterwards put into the experimental installation at Leeds has a perfect record for permanence and reliability.

Mr. Fowler adds that:—

> "One difficulty with apparatus depending for its action on the rate of flow of sewage is that the cycle must vary with the flow, and is shortest when this is at its height; an increased flow, however, in dry weather coincides with the strongest sewage, and therefore some method of ponding-up would have to be resorted to in this case." [*Interim Report*, vol. II., p. 466.]

It may be pointed out that the shortening of the cycle which is referred to cannot be set down to the gear, but will always occur when a varying flow of sewage has to be dealt with on a limited area of filters, unless, as suggested by Mr. Fowler, ponding is resorted to.

This principle was adopted in the works which were laid down

AUTOMATIC WORKING—*continued.*
in 1898 from the writer's designs for the town of Barrhead, near Glasgow, where the flow to the filters is absolutely regulated by means of modules.

Mr. Fowler's subsequent experience appears to have led him to attaeh less importanee to variations in the length of the cycle :—

> "Resting periods.—Experiment has shown that purification effeeted depends rather upon the amount of effluent dealt with per given area than upon the length of cycle employed. Two short cyeles and one long one in the twenty-four hours give results equal to, if not better than, three eyeles of equal duration. Variations in the rate of flow ean thus be dealt with, and in eases of large inerease of flow the rate of working of the beds may be temporarily inereased without subsequent ill effeets." [Fowler, *Interim Report*, vol. II., pp: 467, 468.]

Mr. Fowler's observation that an inereased flow in dry weather coineides with the strongest sewage is illustrated by a table aeeompanying his lecture at the University of Manehester. According to this, the fluctuations in strength lag somewhat behind those in the flow, the minima oeeurring about 5.30 a.m. and 9 a.m. respeetively, and the maxima at 2 p.m. and 4 p.m. It is interesting to note that the results in question are in elose aeeordanee with those of a similar series of determinations made by the late Mr. Perkins, City Analyst of Exeter, on the flow to the septic tank installation at St. Leonards, whieh forms the principal subject-matter of Mr. Cameron's evidence.

(See also 681, 760, 2187, 4013.)

MULTIPLE CONTACT.

In the Sutton system devised by Mr. Dibdin two sets of filters are used, the prineipal funetion of the upper or eoarse beds being to retain and digest the suspended matter in the sewage, the lower or fine beds being more partieularly eoncerned with the oxidation of the dissolved impurity. Where septic tanks are used, eoarse filters are generally dispensed with and fine beds only employed ; but in some eases, where the strength of the sewage is such that a single eontaet, following the septic treatment, is not expeeted to give the required purification, a seeond set of fine beds is laid down.

MULTIPLE CONTACT—*continued.*

The Manchester Experts, in their Report dated 30th October, 1899, state the following conclusion :—

> "That inasmuch as a bacterial contact bed can only effect a definite amount of purification in a single contact, it becomes necessary, in order to carry the purification beyond this limit, to apply the effluent to a second bed, in which again a further definite amount of purification can be effected. Hence, for obtaining a high degree of efficiency in the bacterial purification of sewage, a system of multiple contact is generally necessary. Thus, it may be taken broadly that in the first contact 50 per cent. of the dissolved impurity is removed, and that in the second contact 50 per cent. of the impurity still remaining in the effluent is disposed of, and so on." [*Manchester Report*, p. 53.]

It will be shown later (p. 256) that a single contact, properly managed, is capable of effecting as much purification as would be obtained from double contact on this basis.

While many sewages can be satisfactorily purified by means of a suitable preliminary treatment and a single contact, and others are so strong as to require two contacts, it is a matter of common experience that there are others again, which, with a single contact, yield effluents which sometimes come within the prescribed limits of impurity, but at others transgress them. For these it would manifestly be sheer waste of money to put in a complete plant for double contact; yet it is equally obvious that something must be done to bring the effluent up to the prescribed standard. A simple and effective method of doing so is described by the Manchester Experts in their Report :—

MIXING EFFLUENTS.

> "We have, further, quite recently obtained results which indicate that a most important economy may, by suitable management, be effected in the area required for efficient bacterial treatment. Thus, we have found that, by mixing the effluent from a first contact bed with that from a second, a liquid is obtained which stands the incubator test and is incapable of putrefaction. . . . This method of treatment, which may be described as consisting of one and a-half contacts, most closely fulfils the necessities of the situation; for, as our long experience shows, single contact cannot safely

be relied upon to effect purification, whilst double contact is generally more than sufficient; and the mean of the two, or double contact for one half and single contact for the other half of the sewage, produces an effluent which, as the table shows, is above suspicion.

"Although we do not propose to suggest that the area of contact beds should be reduced to conform with this novel method of treatment, it is obvious that the possibility of satisfactorily dealing with the sewage in this manner will afford more abuudant opportunities for resting the beds and meeting other contingencies than we had before contemplated." [Manchester Report, p. 38.]

This proposal was referred to in the evidence, and is dealt with also by Dr. Rideal in his book on "Sewage and its Purification."

"And you find that by mixing single contact effluent and double contact effluent, you were able to bring about non-putrefactive mixture?—Oh, yes." [Fowler, 5608.]

"It has been suggested by the largest authority we have in the watershed, viz., Manchester, that they might take, say, a million gallons of a tank effluent and mix it with, say, five million gallons of an effluent after bacterial treatment. Such a mixture would comply with the permanganate test and the albuminoid ammonia test, but it would not comply with the incubator test carried out as I have described." [Scudder, 6056.]

"The observation is confirmed that by mixing a nitrated effluent from a 'second contact' bed with that from a first, a liquid is obtained which withstands the incubator test; and it is suggested that this is a novel means by which only one-fifth of the total acreage of the filters need be at a lower level.

"A practical advantage accruing from these experiments is, that the area of the second contact beds may be considerably reduced, so that in many cases it is possible to place the outfall works on a site that would otherwise not be available. At Manchester, experiments have apparently not yet been made ou the lines which I indicated some years ago, of introducing a portion of the nitrated effluent into the septic tank itself. It is obvious that the denitrification change which takes place on mixing the effluents from the first and second contacts is due to the reaction

MIXING EFFLUENTS—*continued.*

between the nitrates in the second and the organic matter in the first, and that this change could be induced earlier in the process as soon as the organic matter is in a soluble re-acting condition. It is also clear that a denitrification change can be more economically conducted in a tank which is continuously full, than in a filter bed constructed for aeration.

"Probably the previous observations of Adeney, Scott Moncrieff [Patent 4994, March, 1898], and others, had been overlooked; compare also my lecture at the Sanitary Institute on December 9th, 1896." [*Journal Sanitary Institute,* xviii., I., p. 75.] [Rideal, *Sewage and its Purification,* p. 232.]

ONE SECONDARY FILTER AFTER TWO PRIMARY ONES.

An alternative means to the same end is indicated in the following evidence, which also relates to the Manchester experiments:—

"And I think you have found that the work of the secondary beds was much lighter work than that of the primary beds?—Unquestionably. [Fowler, 5599.]

"That the bacterial action was more rapid upon dissolved than upon suspended impurities?—There is no doubt of that, I think. [5600.]

"And I think you reached this result, did you not, that you could use one secondary bed as following two primary beds?—I think we have proved that almost to demonstration." [5601.]

"Although in the first instance we gave equal periods of contact in the first and second beds of our experimental installation, we always had in view the possibility of modifying not only the number of applications per twenty-four hours to the beds, but also the possibility of varying the quantities of sewage applied to the upper and lower beds respectively.

"Thus, after finding that an effluent of practically uniform excellence could be obtained by the use of double contact, experiments were made to ascertain whether the upper or the lower beds would admit of harder work without prejudicing the character of the final effluent. These experiments showed that the final beds could be treated with a much

larger volume of sewage than the upper beds, a result which is of obvious importance, not only with respect to the acreage required for the purification, but also in respect of the manner in which that acreage should be laid out, a larger area of upper than of lower beds being required.

"It was further found that the effluent from the upper beds could be most conveniently allowed to flow through the lower beds, thus avoiding the necessity of opening and closing the valves on the lower beds, and thereby saving labour." [Dr. Frankland, 9927.]

"When we passed the effluent from the upper beds through the lower beds at twice the rate, we found that we were still getting an excellent effluent." [10087.] See Pickles, 15332. See also p. 318.

An installation consisting of two septic tanks and four upper and two lower filters, each of the latter receiving the discharges from two of the former, has just been completed from the writer's designs at Lötzen, Germany; but, so far as he is aware, the principle under consideration has not been recognised as yet by the Local Government Board in any scheme sanctioned by them in this country. They have, however, sanctioned a scheme in which the desired economy in filter area is effected, though on somewhat different lines. The scheme in question, for which the firm in which the writer was lately a partner acted as consulting engineers, deals with the sewage of Yeovil, for which, in view of its exceptional foulness, a second contact was considered desirable. The works, in accordance with the standing rule of the Board, are capable of dealing with three times the dry-weather flow; but, instead of placing all the filters at one level, as is usually done, one-half of them were set below the others, so as to deal with the effluent therefrom in dry weather, when they were not required for storm sewage. In wet weather, when the flow increases beyond the capacity of the upper filters, the lower ones are automatically brought into use as first contact beds.

Water Capacity.

Since the method of working a contact bed consists in filling and emptying its interstices, it is important to know what proportion these bear to the total cubic contents of the bed, and whether this ratio is constant or is lowered by use. In the case of coarse beds receiving crude sewage, it has already been

WATER CAPACITY—*continued.*

remarked that the water capacity undergoes serious diminution as time goes on; and inasmuch as the effluent from septic tanks always contains a certain amount of suspended matter, it might be expected that the filters receiving it would eventually show some loss of capacity. This point was accordingly closely inquired into by the Commissioners:—

> "Can you tell us anything about the conditions of the filters after this twenty-six months of work?—Yes, my Lord. There has formed on the surface of the filter, and more notably recently, a black deposit. In wet weather it forms a black slime on the surface of the filters; in dry weather that slime dries quite rapidly, and breaks up. There is also undoubtedly in the pores of the filter, near the top especially, an accumulation of the same sort. In 1896, when the filters were first set to work, the quantity of water they were able to take in, in addition to the filtrant, was 8,962 gallons, or ·39 of the contents of the whole filter. The tests made the other day (last week) showed a quantity equal to 6,349, or ·28 of the contents of the filter. I rested one of the filters (No. 2), and I discharged the water in it, and then measured the flow to it, when I found it to be 7,170 gallons, or ·32 of the contents of the filter." [D. Cameron, 1887.]
>
> "The question of the lasting power of the filter is important, and my experience on this point is that the material does undergo a change, and that the quantity of liquid that could be passed through does diminish in the course of time. How long it will take to become inefficient, time alone can show. We have not yet had sufficient experience, and upon the cost of working, the artificial process largely depends." [Roscoe, 3510.]
>
> "And what reduction of the capacity should be allowed for the matured beds?—Taking the average of the four beds that we have at Sutton, and which work very strong sewage, and work very hard, the present capacity averages 21½ per cent. of the cubic contents of the tank." [Dibdin, 3909.]
>
> "Then, so far as your experiments have gone, Mr. Fowler, with these small experimental beds, you have formed the opinion that it is practicable, dealing with Manchester septic effluent, to maintain the capacity of those beds for a sufficiently long period to make it financially practicable to adopt

WATER CAPACITY—*continued.*

that system?—That is my opinion after careful watching." [5650.]

"I should wish also to add that if a material can be found for contact beds of even size and not liable to reduction, the life of the beds would be greatly lengthened, for loss of capacity is due, I believe, more to reduction and consolidation of the material of the bed than to the undigested matters brought down by the sewage." [Harding, 7069.]

"If we go on to another question, have you had any experience about choking in artificial filters?—Simply what I have read and observed. I think they do choke, if you do not have sedimentation; but as far as I can judge, if you have got sufficient tank capacity, say twenty-four hours or more for your sewage, then I think that you may depend upon a fairly constant capacity in the filters underneath, if it is domestic sewage only." [Strachan, 7615.]

"Could you give us any information about the water capacity of your bacterial beds?—I have prepared a table which I will hand in, from which you will see that the water capacity, which was measured on the 24th September, 1898, after about a month's working, was 61,865 gallons, which equals 49·54 per cent. of the total clinker and water capacity; but taking it after they had got into use there was 50 per cent. of water capacity, and when we worked it for nearly four months the water capacity came down to 36 per cent., and then when we worked it a further seven months, and after three and a half days' rest, it was 34·22 per cent. of the total capacity, and then, a month later, after the beds had finished working altogether, we found that it was 29 per cent." [Mawbey, 8281.]

"Then we may take it, Mr. Fowler, that in your experience over the whole period, notwithstanding the changes, rises and falls of capacity, the capacity has been fairly maintained working with septic tank effluent?—Working with septic tank effluent the figures show that the capacity has been fairly maintained throughout that period. [Fowler, 8466.]

"And in the new beds which you are proposing to lay down, which, I think, you are actually laying down, you are endeavouring to arrest on the surface of the bed as much suspended matter as you can by using fine-screened material as the top layer of tho material?—Yes." [8467.]

Water Capacity—*continued.*

"Well, that constant average capacity will not be its full capacity at the starting point?—Oh, no. [8486.]

"And about what proportion should you say was a possible constant capacity?—Well, I think one would be safe in saying from 25 to 30 per cent. of the total water capacity of the tank. That is how we have usually calculated it." [8487.]

"What was briefly the history of the contact beds?—We had only tried them up to that time on the Dibdin principle; that is, crude sewage on a coarse bed, followed by a fine bed; and we got there very good effluents, but the beds sludged up to such an extent that they became unworkable. [Harrison, 14898.]

"Since then we have tried double contact, using septic tank effluent instead of crude sewage, and having two fine beds instead of a coarse and a fine bed. The result has been that we have got better effluents, and so far we have had no appreciable loss in capacity in the first bed." [14899.]

"The second, which was then the only fine bed, and now is the second fine bed, has not been changed since it was originally laid down?—That is so, it has been in work now five or six years. [14901.]

"And its capacity?—It is about 75,000 gallons." [14902.]

"A cubic yard, when it is first put in, I find will hold 88 gallons, whereas, when it has been working for a period extending over eighteen months to two years, we find that we can maintain 29 gallons per filling, so that it is reduced about two-thirds. [Pickles, 15296.]

"Is the reduction going on to your knowledge in any of your beds?—No, Sir. We believe, from our experience, we can maintain it at that, or about that." [15297.]

Causes of Loss of Capacity.

The causes of the loss of capacity at Leeds are set forth by Colonel Harding, as follows:—

"The loss of capacity would seem to be due to the following causes, some of which are remediable, and others not:—

(1) The passing of sand, coal dust, and road detritus into the bed.—These matters must be kept out, for bacterial action cannot reduce them.

(2) The degradation of the material of the filter.—It is found that coke, though at first carefully sorted to

CAUSES OF LOSS OF CAPACITY—*continued.*

larger size, soon becomes broken down. No doubt this arises to a less extent with clinker, which, however, is apt to take the form of slabs, and is not very suitable for a coarse bed. Burnt ballast is very liable to reduction.

(3) The consolidation of the material of the bed.—In connection with the single contact beds, Nos. 7 and 8, the loss of capacity in those cases was largely due to this cause. The material of a bed must be of very even size, or gradually the smaller pieces, by the slight movement due to filling and emptying, tend to fit themselves in between the larger, so as to approximate to a solid mass. As we have seen, even equal sized material in course of time becomes broken down into unequal, and so consolidation takes place.

(4) More organic solids coming on to the bed than the bed can digest.—Fibre and certain vegetable matters are very slowly dissolved, and tend to accumulate in the beds unless the rate of working is very slow. The screening off of some of these matters can be accomplished within reasonable cost.

(5) The presence in the sewage of matters which cannot be reduced by bacterial action, other than the sand and road detritus.—Whether such matters exist in the sewage in an originally irreducible form, or whether such irreducible form is reached as a result of change in the bed, it is difficult to determine. But it is certain that a coarse bed which has been long at work is found to contain a large quantity of matter akin to humus or garden soil, and which cannot be further reduced.

(6) The retention in the bed of mineral solids originally in solution, but which, by the oxidising action of the beds, come into suspension; as, for instance, the iron liquors containing ferrous sulphates and chlorides, a large part of which are found to be rctained in the beds, the pieces of coke being often heavily coated with red iron deposit." [7063.]

CAUSES OF LOSS OF CAPACITY—*continued.*

It may be added that over and above the actual deposit on the surfaces of the filtering material of solid particles from the sewage, each piece of material gradually becomes covered with a spongy bacterial growth, which, if the beds are worked too hard, seriously reduces the water capacity.

> "These beds should be filled with either coke, burnt ballast, or other suitable substance which has been rejected by a half-inch mesh in order to exclude dust and small stuff, and thus lessen the chance of clogging from the accumulation of sludge and the zoöglea form of bacteria, which, by its gelatinous character, under favourable conditions, might develop to a sufficient extent to assist materially in rendering the filter waterlogged." [Dibdin, *Purification of Sewage and Water*, pp. 129, 130.]

This growth can readily be kept within bounds by resting the filter.

The loss of capacity which takes place while a bed is getting into condition is often confused with "sludging up," and some startling calculations have been based thereon. Particulars of this initial loss of water capacity by the filters laid down by Mr. Cameron at Belleisle, Exeter, computed from measurements by the writer, are given in the following table:—

Average of all Filters.	Gallons.	Percentage of Total.
A.—Total cubic contents	23,431	100 per cent.
B.—Effluent sent in at first filling (August 15, 1896)	13,775	59 per cent.
C.—Effluent sent in at second filling (August 21, 1896)	10,302	44 per cent.
D.—Effluent sent in in regular working (November 14 and 15, 1896)	7,983	34 per cent.

These figures show a successive decline, which may be accounted for under three heads:—

Difference between A and B, representing the actual solid volume of the material, less its water of saturation,
9,656 gallons, or 41 per cent.

Causes of Loss of Capacity—*continued.*

Difference between B and C, representing the water originally required to saturate the material and held therein by capillarity - 3,473 gallons, or 15 per cent.

Difference between C and D, representing increase of capillary water, suspended matter deposited in filter, and bacterial growths - - 2,319 gallons, or 10 per cent.

The loss of 10 per cent. from C to D is probably due almost entirely to growths and consequent increase of capillary water, as the tank effluent during the intervening period contained no great amount of suspended matter.

Many calculations of loss of water capacity have been vitiated by the failure to allow the same length of time to elapse in all cases between the last discharge of the filter and the measurement.

It may be remarked also that by far the greater number of the observations as yet recorded on the subject have been made on experimental filters. These filters were laid down in the absence of any previous experience in the preparation of the filtering material, and had, as a rule, to deal with the effluent from experimental septic tanks, yielding unduly high amounts of suspended matter. There is, therefore, good ground for expecting that, with the experience now available, very much better results will be obtained.

The assumed necessity for renewing the material in contact beds at the end of a few years has been pointed to as a fatal objection to their use. It will be shown later (pp. 262, 263) that in the event of the material becoming clogged its capacity can readily and cheaply be restored by washing it, and that even if it should become necessary to renew the whole of the material at the end of six years, the cost of doing so would not be prohibitive.

Life of Filters.

No definite information as to the life of contact beds properly prepared and worked is likely to be forthcoming for several years; but the experience already available shows that filters, the material in which was originally none too good, may be kept in constant hard work for six years, without any material loss of capacity, and at the end of that time still produce an excellent effluent. Some indication of the life of streaming filters under

adverse circumstances is afforded by the experience obtained by Mr. Santo Crimp at Wimbledon, and referred to in the following answer:—

> "I should say that we have one filter there which was made in 1876, which was originally 5,000 square yards in area, and that filter has been used for crude sewage, I think, since that time; since 1876." [Crimp, 1598.]

Depth of Contact Beds.

The evidence shows that the efficiency of contact beds is not dependent to any appreciable extent on the depth of the material, which will therefore be determined in any particular case by considerations of convenience and cost. They are generally made as deep as the fall will permit, since, as a matter of construction, it is cheaper to provide a given capacity in a deep bed than in a shallow one.

The filters at Exeter referred to in Mr. Cameron's evidence are 5 feet deep. [1872.]

> "Wo found at Exeter, from taps placed on No. 3 filter so as to be able to draw off at every foot down, that the maximum purification took place at 3 feet, consequently I recommend that the filters should not now be more than 4 feet in depth." [D. Cameron, 2052.] [See p. 222.]
>
> "How did you find the depth of your beds affect their working?—We constructed our second and third pair of beds with a depth of only 3 feet, in the belief that we should secure better aeration, and that we should be able to give more frequent fillings. We hoped that with shallower and, therefore, cheaper beds we could by more frequent fillings deal with as great a volume as on the deeper and more expensive beds; but we were disappointed. The results were never so good as with the deeper beds, and we could not give more fillings. Our experience was in favour of the deeper beds, and this is of special value where the available area is limited." [Harding, 7050.]
>
> "Our experience, of course, has been limited to the beds we have had at Leeds, and our deepest bed was 6 feet. So far as our experience goes, the greater depth gives a better result, but I am unable to say from actual experience how far increase of depth beyond 6 feet would give improved results or the contrary." [7092.]

DEPTH OF CONTACT BEDS—*continued.*

"In your answer to another question, your experience in view of the deeper beds strikes me as curious. I see that you expected to find that in shallower beds you would get some more aeration ?—My own idea was that by having shallower beds you would probably be able to pass a larger volume of sewage through them than through deeper beds, and that would be much less costly to construct. The idea, therefore, was that the periods of aeration could be reduced, and so the number of fillings increased, and I was much disappointed to find that the result was not obtained." [7127.]

"I might just on that point remind Professor Ramsay that Mr. Fowler, of Manchester, has tried a shallow bed 15 inches deep with good results." [7135.]

"An interesting point to ascertain would be whether it is better to use a shallow than a deeper bed, and this 15-inch bed seems to have given you very good results ?—My own feeling would be that if you had acreage enough it would be advantageous to do so. The bed drains so rapidly, and you get it very easily aerated, and certainly my own preference would be for shallow beds, supposing you had a sufficient area of land." [Fowler, 8479.]

"And your experience in working that bed with storm waters, and of a shallow depth of 15 inches, has been encouraging ?—Very encouraging." [8482.]

With a view to increasing the amount of sewage which can be dealt with on a given acreage, and so keeping within bounds the area of beds required for dealing with the sewage of the Metropolis, the advisers of the London County Council have laid down a contact bed with a depth of no less than 13 feet. In Dr. Clowes' third Report to the Council he refers to this filter as follows :—

"The purification effected by this bed, as judged by the removal of dissolved organic matter, was practically equal to that obtained by the 4-feet bed. There is no reason why a deep bed should not give as good results as a shallow bed, provided that it is as well aerated during the periods when it is empty. Experiments have been already reported which proved that even the bottom of the 13-foot bed was well supplied with oxygen. The effluent from this deep coke-bed has been usually slightly turbid ; it possessed only a faint earthy smell, and it was capable of supporting fish life." [*L. C. C. Third Report*, p. 15.]

It will be evident from this experience that no limit can safely be assigned to the depth at which nitrification takes place. The opinion was formerly prevalent that this action ceased in soils at a depth of about 3 feet, but Mr. Warington's experiments, cited by Dr. Frankland, and referred to on p. 146, show that it goes on at a much greater depth.

There is little doubt that, given suitable conditions as to the supply of food and air, and an equable temperature, the work of the nitrifying organisms will not be affected by the thickness of the superincumbent material. The falling off in nitrates observed by Mr. G. H. Martin at the 4-feet depth in the Exeter filters, and referred to later (p. 222), can be fully accounted for by the conditions under which these particular beds were worked.

Maturing of Contact Beds.

Evidence was given as to the time required to bring contact beds into condition, and the improvement in their efficiency which subsequently takes place:—

> "A filter once started, if it is properly worked, should go on improving, and should be able to deal with a larger and larger quantity of sewage as time goes on. Of course, it would be necessary to make allowances for any mechanical filling of the filter with sand or clay or mud, or anything of that kind; but, if proper precautions are taken to keep out the inorganic substances, the filter should go on working indefinitely after it is properly 'balanced.'" [Woodhead, 2817.]

> "At the same time, with that change in the character of the surface—the efficiency, the chemical and bacteriological efficiency—of the filters appears to increase. . . . So that during the last year our results have undoubtedly been chemically more satisfactory than in previous years." [Roscoe, 3524.]

> "What time elapses before a bed is matured?—At Sutton we began to get good results in about three weeks. At Leeds, I think, it took something like—more like three months; but, of course, a good deal depends upon the temperature and the season. If it is in the summer time, I should say you would get a bed into a fairly mature condition almost in a matter of days." [Dibdin, 3926.]

"When you made these comparative tests, had the septic tank and tho contact beds reached their full working conditions?—Well, I do not know that they have now, because there seems to be a gradual improvement going on in these beds." [Latham, 4571.]

"What was the period of incubation for the beds?—It was found that new beds required about six weeks to get into condition, the early effluents being unsatisfactory and putrescent; but at the end of this period a rapid and permanent improvement in the filtrate took place." [Harding, 7056.]

"There is only, I think, one other point. I notice, that if you take the quarter ending September 26th and the quarter ending December 26th, in tho first case the quarter is warm weather, you have 1 in 2 of the effluents in the coarse beds A and O putrescible; and in the cold weather, in the quarter onding December 26, you have only 1 in 16 putrescible?—Certainly. [Fowler, 8547.]

"And the same thing holds good for the effluents from bed B, practically speaking. Was that due to the great dilution in winter, or what was it?—No, I think it admits of a simple explanation, namely, that during the earlier period our septic tank effluent did not come thoroughly into condition. That is one of the results which leads me strongly to the opinion that you require to have a thoroughly septicised effluent to get very good nitrification." [8548.]

"And your experience about filters generally, I gather from what you said, is that they are more effective after they have been matured?—Unquestionably." [8555.]

Mr. Mawbey's experience, however, has led him to form an opposite opinion:—

"Did you find that the efficiency of the beds increased with time or otherwise?—Well, that is a strange thing, my Lord, we did not. You will find, if you examine those tables, that the efficiency of those beds, both for suspended matter and chemical, was no better in the last period of the time than in the first period; they wore just about equal. There was no improvement, and in fact I should be rather inclined to think that unless they had very ample rest they would be more likely to slightly deteriorate than improvo. They did not improve." [8282.]

N 2

CHAPTER XIII.

FLOW FILTERS.

STREAMING FILTERS.

THE filters used in connection with chemical precipitation were, for the most part, worked on the streaming principle, which is described by Mr. Dibdin as follows:—

"I may explain what I mean by streaming. That is, the beds are then worked in the same manner as that in which a water company works its filters. The water stands on the top of the beds, or just level with the top, and it is allowed to flow out only at the rate at which it flows in, so that there is no special rush of water downward through the material of the bed; otherwise it would act merely as a sieve, and you would get no quiet sedimentation taking place. But where the whole body of the bed is allowed to come into play by the water slowly finding its way down from the top to the bottom, and into the under-drains, you then get the maximum effect of the beds used in this case as ordinary filters, the sewage matters deposited in them being destroyed in the course of time by the bacterial action." [3802.]

The working of the filters at Chorley is thus described by Mr. Alderman Hibbert:—

"The precipitated effluent is distributed on to the filters by means of syphons. The syphons unseal every 40 minutes, and cover the filtors 3 inches deep with water. Tho capacity of the syphon chambers is 2,400 gallons. This quantity of water is therefore sent through the filters every 40 minutes; there is thus a layer of air between each filtration, or passage of the water through the filters, which undoubtedly purifies the interior strata." [7761.]

The filters are washed weekly.

Tho "controlled filters" laid down by Mr. Baldwin Latham at Friern Barnet, in 1885, are worked on the same principle:—

"The filters are 6 feet deep, and the bottom of them is burnt ballast to a depth of 2 feet 6 inches. On the top of this is a mixture of burnt ballast, breeze from the gas works, and sandy soil, 3 feet deep, and over the whole surface of the filter a layer of fine sandy soil, 6 inches in thickness, is placed so as to control the rate of filtration through every part of the filter.

"In a system of this kind it is essential that the sewage should be distributed over every part of the filter, so as to pass uniformly through each part." [Latham, *Interim Report*, Vol. II., p. 270.]

Trickling Filters.

Trickling filters differ from streaming filters in that the effluent is not allowed to flood the surface of the beds, but is showered or sprayed on to them. This in some cases takes place continuously for several hours at a time, while at others the filters are fed intermittently.

The largest filters as yet at work on the continuous flow system are those laid down at Salford from the designs of the borough engineer, and described in his evidence as follows:—

"This scheme was put before the committee just eight and a half years ago to-day, to the day in fact, and so it was designed completely before the modern septic system or the term 'bacteria bed' was in use. We called them 'aerating filters' when we began with them, but to adopt the term now ordinarily in use they are 'bacteria beds.' These bacteria beds are a special feature, just as the gravel bed probably is, seeing that they are open beds for what is now called the trickling system; not holding up and letting go, which has been called the Dibdin system, but trickling through. I, in fact, based this scheme on the Massachusetts experiments, which are on the trickling flow system. [Corbett, 15431.]

"What is the area of these aerating beds?—26,000 square yards, the aerating beds. [15432.]

"What is the area of your roughing tanks?—2,040 square yards, so that it is a very rapid flow through tho gravel, simply a straining action. [15433.]

"Then tho effluent from the gravel bed is distributed by

TRICKLING FILTERS—*continued.*

a special mechanism over these large aerating beds?—Yes, and you will see that; and that is why we have fixed sprinkler jets, and not the moving sprinklers that are used in many cases. [15434.]

"We shall see these in operation?—Yes, you will see these, and they will be better than Whittaker's. They sprinkle the whole area of these aerating filters. [15435.]

"What is the depth of these filters?—There is 5 feet depth of material now, but we are proceeding to fill them to a depth of 8 feet. [15436.]

"Then, what is the material of which they are constructed?—Cinders, such as come from destructors and all boiler furnaces. [15437.]

"Of varying dimensions?—Of a size that will pass between holes of three-sixteenths of an inch, and three-quarters of an inch diameter. [15438.]

"Selected?—It is all screened in revolving screens with round holes of that size. Then the floors of these several filters are covered with tiles on short legs, forming a sort of false floor, with a complete open air space underneath giving a free vent for the water, and also for the spent air from the filter. Our intention is that the air and water should go down together, the air to escape freely with the water by the open floor into the large culverts which are provided, and which have frequent manholes for blowing off the air. And we have tested everything by years of experiments, and have made little model filters, some of which you can see still existing, and we have ascertained that with a good chemical tank effluent, which is the first essential—with a good chemical tank effluent, we can use these filters night and day without intermission for very long periods." [15439.]

Trickling filters on the continuous flow system have been used at several places in Derbyshire, among others Chesterfield and Buxton, and at Lichfield, the sewage in each case being first treated by precipitation.

Information as to the Derbyshire filters and the results therefrom is given by Dr. Barwise. [4030 *et seq.*]

The principle of continuous flow is also adopted by Mr. Stoddart, whose work will be referred to later in connection with modes of distribution (p. 184).

Intermittent *versus* Continuous Working.

On the other hand, the necessity for intermittency was insisted on by several witnesses:—

> "I think artificial filtration may be safely adopted, provided it is worked according to suitable conditions, intermittency being a vital condition for efficient results." [Scudder, 518.]
>
> "Do you consider it absolutely necessary to shut off the filter for twelve hours in order to produce the results that you obtain?—It is absolutely necessary to give it some rest." [Garfield, 3475.]
>
> "Do you suggest that the intermittence has, among others, this advantage, that you may work with a smaller head?—Yes, where the flow is limited. [Candy, 7021.]
>
> "Then what other advantages do you claim for the intermittence?—That we avoid the growth upon the surface of the bed, and that growth leads eventually to clogging; all these short intervals of rest, say three minutes out of every four minutes, are most beneficial." [7022.]

The need for intermittency in connection with streaming filters was referred to by Alderman Hibbert [7927] and Mr. Fowler [8530].

Mr. Stoddart, on the other hand, regards intermittency as wasteful. [See *Interim Report*, vol. II., p. 291.]

Colonel Harding says of the Candy sprinkler (of which he expresses general approval) that it "has the disadvantage of being intermittent, and causing the sewage to pass through in rushes." [7453.] [See p. 187.]

In the foregoing extracts from the evidence, the question of continuous *versus* intermittent flow has been dealt with chiefly as regards its desirability or otherwise from a bacterial point of view; but in practice a further consideration arises, namely, that of securing a uniform distribution of the effluent. It is often held to be impossible to distribute the effluent uniformly over a filter unless the rate of flow greatly exceeds that with which the latter is capable of dealing continuously. It is for this reason probably, rather than on purely theoretical grounds, that the majority of trickling filters are fed intermittently.

Distribution.

In every flow filter, of whatever kind, the prime necessity is to distribute the effluent with approximate uniformity over its surface.

With a streaming filter such as those at Chorley, or the controlled filters laid down by Mr. Baldwin Latham at Friern Barnet, this is effected by means of the top layer of the filtering material, which is made fine for that purpose; but in a trickling filter the use of a fine upper layer would be out of the question, as it would defeat one of the chief objects in view, namely, the freest possible circulation of air through the bed. Various means of distribution have been adopted. In Derbyshire, fixed perforated pipes are used, which are described by Dr. Barwise as follows:—

> "The particular arrangement which seems to me to act best is an arrangement—not a patented arrangement—simply an arrangement of iron pipes with quarter-inch holes in them, over the top of the hole a plate of metal, the pipes being fed by an automatic flushing tank. What happens is this, that when there is a head of two feet the sewage impinges on the metal disc, and spreads out in a wide circle; as the head diminishes the circle narrows, so that you get practically the same effect as a watering-can over the surface of the filter." [Barwise, 4033.]
>
> "They are wrought-iron pipes—very roughly made." [4035, 4036.]

At Salford also the distribution is effected by means of fixed pipes, but these, instead of being perforated at short intervals, are furnished with special brass jets, spaced 10 feet apart in one direction, and 5 feet in the other. They are worked under a head of some feet, and are so proportioned as to limit the flow to the beds to the intended quantity. [See 15482 *et seq.*]

Mr. Stoddart's patent distributor is described by him as follows:—

> "The distributor, a model of which is exhibited, consists of a gutter-shaped vessel, provided along its underside with a series of vertical points. The tank effluent passes along the gutters, overflows its margins, and on reaching the nearest point drops from it upon the surface of the filter.

"In practice, the distributors are formed from a corrugated sheet of special design, slots being punched at intervals to allow the tank effluent to reach the under surface.

"This form of distributor requires only sufficient head to allow the tank effluent to find its way to the under surface—that is about an inch—and is perfectly indifferent to climatic changes, discharge of sludge from the tank, and like accidents, and has never been interrupted in its action from any cause of the kind, although from reasons connected with the filter it is well to keep the distributor fairly free from deposited solids.

"Having no moving parts, and no fine apertures, there is nothing in the distributor capable of being disarranged or thrown out of action." [*Interim Report*, vol. II., p. 290.]

With the exceptions above described, the distributors used in connection with trickling filters are intermittent in their action.

Colonel Ducat and Mr. Scott Moncrieff use a series of tipping trays, spaced at short intervals over the whole filter:—

"On one main wall of each filter its own feeding channel will be built of cement, and will be furnished with little weir sluices and shoots discharging the sewage into iron distributing channels, placed about 1 to 1½ ft. apart, and extending transversely across the top of the filtering material. These distributing channels will automatically tip and discharge their contents when full, and right themselves again when empty, so that no sludge will collect and settle in them, and the whole working of the filter will be as nearly automatic as possible, human agency merely being wanted to see that no channel gets blocked or fails to work properly." [Ducat, 2186.]

Rotary Sprinklers.

The majority of trickling filters, however, are fed by what are known as "rotary sprinklers," consisting of pipes pivoted in the centre of the filter, and having perforations, on the opposite sides of the two arms, from which the effluent is showered on to the bed, the reaction of the liquid against the side of the pipe being utilised to rotate tho sprinkler, after the fashion of a Barker's mill. As the sprinkler revolves, the points of impact of the jets are continually changed, tracing out on tho surface of the filter a series of concentric circles, the distances between which are

Rotary Sprinklers—*continued.*

governed by the spacing of the orifices in the pipe. It will be seen that the rotary sprinkler constitutes a simple and effective means for securing an intermittent application of the effluent to each part of the filter, in conjunction with a continuous flow to the latter taken as a whole. The interval between successive applications of effluent to the same spot varies with different distributors, and will be referred to later on in connection with the Hanley experiments (p. 255).

Several types of rotary sprinklers are on the market, some of which were specially referred to before the Commissioners.

The first of these was laid down by Mr. Whittaker at Accrington, and is mentioned, though not described, in his evidence. [See 4758 *et seq.*] It was followed by the Candy-Caink distributor, which is referred to by Mr. Candy as follows :—

> "I consider it a great advance upon anything done up to the present day in the way of distribution. [Candy, 6993.]
>
> "The revolution of the sprinkler is effected by a small head of water ?—The revolution is caused by the reaction of the water issuing from the holes in the pipe, and we find that we can reduce that head to even three or four inches. As long as we keep the mouth of the distributing pipe submerged we get the reaction and sufficient power. [6994.]
>
> "And by what means is the uniformity of the distribution secured ?—By different distances of perforation along the pipes, and also by the size of the perforations. Those vary according to the length of the pipe. They might commence with one-eighth of an inch diameter and extend up to three-quarters of an inch. The number and size of the holes are worked out mechanically in accordance with the number of gallons we want to distribute per square yard, based on the maximum quantity required upon any given yard, and whether that yard is close to the centre or at the extremity of the pipe the distribution per square yard is equal. [6995.]
>
> "And the clogging of the holes is prevented by what means ?—Upon and in the basin of the coarse bed there is a screen which will prevent any filamentous or large flocculent matter from getting into the holes. The holes will become somewhat interrupted, and it is necessary that there should be an attendant to look after it; probably once a day it will take him five minutes to run up a brush on the outside.

ROTARY SPRINKLERS—*continued.*

The clogging matter is easily disturbed, because you have the pressure from the inside, which will drive out any material. [Candy, 6996.]

"How often do you find it necessary to clean out the tubes inside?—(Mr. Prescott): I should say about once a week." [6997.]

In order that the sprinkler may receive the effluent at the rate necessary for its efficient working, without overcharging the bed, Mr. Candy makes the flow to the former intermittent. [See 7016 *et seq.*]

Mr. Prescott, then Borough Surveyor of Reigate, in his report to the Sewage Farm Committee, spoke in high terms of this sprinkler:—

"The value of the method adopted for treating the bed with the sprinkler appears, therefore, to be as follows:—In its fall from the sprinkler to the surface of the filter bed the effluent absorbs a barely appreciable amount of oxygen, so that the high figure of dissolved oxygen found in the effluent as it emerges from the bed is doubtless due to the manner of its distribution in its passage through the filter.

"The descending effluent arranged in spiral films alternating with layers of air constitutes an arrangement admirably adapted to ensure thorough aeration not of the effluent only but of the filter bed itself. . . . . I have no hesitation in affirming that the 'sprinkling process' is the only satisfactory one for Reigate, and my conclusions are based on the very exhaustive and critical trials carried out on your own works during the past two years." [6986.]

Colonel Harding compares the two types of sprinklers as follows:—

"Do you prefer that to a Whittaker?—Yes, although the Candy sprinkler has the disadvantage of being intermittent, and causing the sewage to pass through in rushes. To that extent it is a disadvantage. On the other hand, the Candy sprinkler has this advantage, that while it works, it works at a greater pressure, because out of five minutes it only works one minute, and whereas the same volume would be spread over in five minutes by the Whittaker sprinkler, that volume passes through in one minute by the Candy sprinkler, and while it works at a greater pressure the holes are more easily kept clean. It does not want so much attention, and

ROTARY SPRINKLERS—*continued.*

it also works with a smaller head. Incidentally there may be this further advantage in the use of the Candy sprinkler for use with crude sewage, that the intermittence has some effect in choking the growth of the pilobolus on the surface. [7453.]

"Which tends to block the surface?—Which tends to block the surface in continuous filtration. I recently visited Bristol, and I saw there the effect of the rain-dropping system of Mr. Stoddart, and there was there a pilobolus growth upon the coke, but the sewage that he is dealing with is so exceedingly weak that it was not excessive, it did not interfere with action, but if we had continuous trickling with the Leeds sewage at anything like the rates which are being used at Bristol, I am quite sure that we should have a pilobolus growth which would stop the action before very long." [7454.] [See also 7374.]

"(Colonel Harding): In using continuous filters distribution is, of course, a great difficulty?—It is the difficulty." [Stoddart, 5047.]

The difficulty referred to by Colonel Harding has been experienced by other users of continuous filters. Dr. Bostock Hill, for instance, speaking at the Provincial Sessional Meeting of the Sanitary Institute, held at Birmingham, in September, 1903, says:—

"Another point which has to be borne in mind in the consideration of streaming filters is the distribution. Many of the results hitherto recorded as obtained in this way have been unsatisfactory because of improper distribution and the loss, therefore, of a considerable area of the filter. This difficulty at the present time looks like being overcome by the introduction of the distributor. One of the earliest distributors put down was the one on the coal beds at Lichfield, by Mr. Garfield. This is very simple, and has exceeded my expectations, because for many years in winter and summer it has acted satisfactorily, while the expense has been but small. A somewhat similar arrangement has been put into force at Salford, but travelling distributors of many kinds are now on the market, and where it is possible to use them better results still ought to be obtained." [Journal San. Inst., vol. XXIV., p. 839.]

Rotary Sprinklers—*continued.*

In connection with the Hanley experiments, Dr. Reid observes:—

"The question of efficient distribution was not an easy one, there being, at the time the design of the works was under consideration, no mechanism available which was completely under control as regards volume delivered per yard of filter or duration of rest periods. Various types of automatic revolving distributors were then on the market, but none of these quite fulfilled the above conditions, and as we were anxious to arrive at a conclusion as to the capability of the plant under ideal conditions, as regards distribution, efforts were made to obtain some appliance which would be under complete control, and allow of adjustment for experimental purposes as regards the quantity delivered, and the intervals of delivery.

"The method of distribution by fine sprays, even had such complied with the high standard desired, was out of the question, because of the nuisance which would undoubtedly have been experienced by the adjoining residents from the fine spraying of a septic effluent over a large area.

"Having talked the matter over with Mr. Scott Moncrieff, who has done so much excellent work in advancing both the science and technique of sewage disposal, he designed an apparatus which was ultimately fixed, and which has been at work in distributing the sewage on a circular filter throughout the time covered by the experiment.

"Later on, Mr. Willcox designed a mechanical distributor which was fixed in connection with a rectangular filter, and that apparatus also has been at work throughout the experiment.

"I do not propose to comment upon the comparative merits of the two apparatus from a mechanical point of view, that being an engineering question, nor am I in a position to compare them from the point of view of capital cost, and working expenses, but, from observations made throughout the experimental working of the plant, I can state that both complied with the stringent conditions as regards efficiency laid down in the first instance, and—I believe for the first time in the history of sewage disposal by artificial filtration—the distribution of the sewage was

under complete control as regards the vital requirements of the biological process of purification" (*a*).

(*a*) As a matter of fact, owing to delay in the construction of the works at Hanley, a Scott Moncrieff distributor was in actual operation in connection with an experimental filter at the Birmingham, Tame, and Rea Joint Boards' Disposal Works a month or two before the apparatus was in use at Hanley. [Hanley Report, pp. 2 and 3.]

Attention required by Trickling Filters.

Evidence was given by several witnesses as to the amount of attention required by filters worked on the trickling system.

The work to be done in connection with the Candy sprinkler was described by Mr. Candy in his answers already quoted (p. 186).

> "Is there not a very great amount of cleaning and poking-out of the holes necessary in connection with the Whittaker?—Very considerable. I believe we are obliged to clean them out almost daily. The rush of water through the holes is very slow on account of the small quantity which passes on—200 gallons per square yard working continuously; and it requires constant attention, and the mechanical contrivance of the Whittaker sprinkler is very far from being satisfactory. [Harding, 7455.]
>
> "And as to cost of picking-out?—Not only serious, but almost prohibitive. [7456.]
>
> "And the Candy sprinkler?—With the Candy sprinkler the trouble would be considerably less; but I hold the opinion that as yet we have no satisfactory system of distribution upon continuous beds. No doubt the idea is to have a distribution of sewage equally over the whole surface. You get that in the Stoddart, but I am afraid that would not act effectually with sewage containing any considerable amount of suspended solids. [7457.]
>
> "Is there much raking out of the Stoddart sprinklers?—The Stoddart distributor requires very frequent attention at Bristol. [7458.]
>
> "The gutters fill up?—The gutters fill up. At Leeds I am quite sure that they would require daily attention." [7459.]

Mr. Stoddart himself says:—

"The channels are continually brushed out once a week. I should like to make this clear, if I may, that the presence of solid matter in the distributor does not in the least degree affect the action of the distributor itself. If the channels are filled with solid matter the tank effluent will pass through the gauges, and drops into the filter as before; but the solid matter begins then to be left in the filter, of course." [5053.]

"Is there much work required to clear the grit from the sprinklers?—That depends on the sprinkler. If the holes are small, and of the same diameter, and are so placed as to give equal distribution over the bed—that is, that they become nearer to each other as they get to the outside of the sprinkler—then there is a difficulty; but if the holes are the same distance apart on the sprinkler, and increase in size in proportion to the area covered, then there is not much difficulty. The pieces of material clogging the smaller holes up are washed out at the next larger holes at the next flush; that is, with the use of the Candy sprinkler where the flow into the sprinkler is intermittent. [Harrison, 14998.]

"How often do the holes require to be cleaned?—With the Whittaker sprinkler they require to be cleaned three times per day; with the Candy once a day is ample. [14999.]

"Is that a serious item in labour; I mean taking it per acre?—Yes; it will be over a large area of beds." [15000.]

Depth of Trickling Filters.

In a trickling filter the depth is of great importance, the amount of purification effected depending largely on the thickness of the layer of material through which the effluent passes.

"The depth of the filtering media should be 5 feet where possible." [Garfield, 3411.]

"We were getting a much better result with 9 feet than we obtained by 4 ft. 8 in." [Whittaker, 4769.]

"Do you think that the greater part of the work is done in the upper layers?—The greater part of the work is done in the upper layers. I may say that the effluent always

DEPTH OF TRICKLING FILTERS—*continued.*

contains in our sewage a fair amount of sediment or suspended matter." [4878.]

"What is the depth of the filter?—6 feet. All these calculations are based on 6 feet." [Stoddart, 5076.]

"As our filters may be but from 3 to 12 inches deep, we can place one above another, and so effect a large amount of filtration upon a comparatively small area of ground space." [Brown, *Interim Report*, Vol. II., p. 296.]

As mentioned later, the "Leeds filter" is 10 feet deep [7379]; the depth was subsequently increased to 12 feet. [15073.]

"I have already prepared plans of four or five acres of percolating beds." [Watson, 14580.]

"What depth of material do you propose to use in these beds?—5 feet." [14583.]

"I have just made a report to the" (Salford) "Committee about the comparative value of the 3 ft. 6 in. filter, the 5 ft. filter, and the 8 ft. filter. I have had some experiments carried on for two years, and I have it in print here. [Bell, 15518.]

"Can you say, very briefly, which gives the best results? —The 8-feet filter certainly does give the best results. 15519.]

"In proportion to its depth?—In proportion to its depth. [15520.]

"I mean the increase of improvement is the same as the increase in depth?—It is. It produces a better effluent; but then the question is, is it worth while increasing the expense? And I have come to the conclusion that the increased improvement was not great enough to warrant me in recommending the 8-feet filter, but certainly the 8 feet is best; there is no doubt about it from the experiments. [15521.]

"And how is the 5 ft. filter as compared with the 3 ft. 6 in. filter?—A considerable improvement. The 3 ft. 6 in. filter did not warrant its adoption. [15522.]

"It was inadequate?—It was inadequate; yes. [15523.]

"The 5 feet?—The 5 feet is what we have got now on the large scale. [15524.]

"Giving the average you have given?—Yes. [15525.]

"What do you get with 8-feet filter?—We get more aeration. But we find that when the albuminoid ammonia gets

DEPTH OF TRICKLING FILTERS—*continued.*

down to a certain state, almost as you might say to minimum, increased oxidation does not seem to increase the purification, which statement I have proved by many experiments. [15526.]

"What is the albuminoid ammonia in tho three cases in the 3 ft. 6 in., the 5 ft., and 8 ft.?—They have varied, of course. They are pretty much the same, but they have varied. Of course, tho 3 ft. 6 in. has been down as low as ·14, and the 8 feet has been as low as ·06; but then it has not kept that up day by day. [15527.]

"And the oxygen absorbed?—And the oxygen absorbed has varied from ·2. We started off on the 8 feet with oxygen as low as ·2 grain to the gallon, which was exceedingly low, and it has gone up to ·5 and ·6." [15528.]

"(Colonel Harding): On the 5-feet scale the results come within the provisional standard of the Irwell and Mersey Board?—Yes; I think they are better." [15533.]

Further information on the subject will be found in Answers 4925, quoted below, 4980, 7033, and 7374.

While no higher limit can be placed to the effective depth of a trickling filter, it appears from the evidence that a certain minimum depth (generally taken as 4 feet) is required. The necessity for this arises partly from the fact that the time occupied in passing through a shallow filter is too short to produce the desired result, but partly from a practical consideration pointed out by Mr. Whittaker:—

"You were saying that the principal action takes place in the upper 3 feet of the filter. Why, then, do you make your filter 12 feet deep?—If you could get it absolutely uniform, so that you would be sure that in each part of the filter the liquor would remain the same length of time, a less depth would be sufficient; but you will find that, however carefully constructed the filter is, that in one particular spot there will be quite a distinct and direct thread of air, and that thread of air would pass too much of the effluent. The extra depth is only to balance what you might call the irregularities of the filter." [4925.]

To guard against the tendency to stream, referred to by Mr. Whittaker, the writer has provided a contact layer in the bottom of several trickling filters which he has designed during the past two or three years.

Time of Passage through Filter.

A point of considerable interest and some importance is the time which the liquid takes to pass through a filter. Colonel Ducat stated that tho flow through his filter "can be made to occupy an hour or more" [2185]; but in practice the time appears to be shorter. In his answer No. 2238, he mentions the time of passage through his eight-foot filter of pebbles as about half an hour, and through his ten-foot cinder filter as longer. Mr. Scott Moncrieff, working with superposed trays of coke some seven inches deep, says that the effluent passes through eight of them in something under eight minutes [3226]; while Mr. Stoddart gives twenty minutes as the time of passage through a Stoddart filter six feet deep. [5075.]

At Leeds "the sewage took only a quarter hour to pass through tho three beds" (having a total depth of coarse coke of 8 ft. 6 in.) [Harding, 7374]; and "in trickling filtration the liquid passes through in a few minutes." [7376.]

Some still more rapid passages wero placed on record by Colonel Harding:—

> "Were you able to gauge how long it took for the sewage to pass through this 10 feet of coke in your Leeds filter?—Yes. We made careful tests to ascertain this. We poured a pint of strong coloured dye upon tho surface of the coke, just as tho Candy sprinkler (which you will remember is intermittent in its action) was starting, and we found to our surprise that the colour began to appear in the filtrate after three minutes, while there was the maximum of coloration within four minutes; so that the liquid takes about three minutes in passing through the filter. This experiment was several times repeated with the same result. We also tried our No. 2, or coarse Whittaker bed, in the same way, and found the colour to come through in 2½ minutes, with full coloration in 3½ minutes. I myself repeated a similar experiment on Mr. Stoddart's filter at Bristol, which has 6 feet depth of coarse clinker, and there found the colour to appear in tho filtrate at the end of two minutes, with full coloration in 3 minutes. In the Ducat bed at Leeds, the material of which is fine, the timo of passage was found to be 15 minutes. When one considers the results obtained in this rapid transit by trickling filtration, they cannot but

strike anyone as very interesting and remarkable." [Harding, 7383.]

The quickest passage noted was $1\frac{3}{4}$ minutes, through tho Leeds filter. [Harrison, 15067.]

The time observed at Salford was $28\frac{1}{2}$ minutes. [Arnold, 15542; see also Garfield, 15147.]

The importance of these results lies in the domonstration which they afford, and to which Mr. Scott Moncrieff calls attention, that the process of nitrification "is an exceedingly rapid one." Further evidenco as to this is afforded by the fact that nearly the whole of the nitrogcn in the cultivation tank effluent was oxidised during the eight minutes occupied by its passage through the trays. That the oxidation was not confined to the nitrogen of thc cffluent is shown by the fact that the oxygcn absorption was simultaneously reduced from 9·843 to 0·397. [Scott Moncrieff, 3222 *et seq.*]

Aeration of Filters.

In order to ensure good results with the trickling system, it is considered essential to keep all parts of the filter fully aerated. The point is referred to by Professor Ramsay, who asked Dr. Rideal:—

"Would it be advisable to blow air through them, or to expose them in some way to air?—Yes; if air was blown through, you would bring more oxygen into contact with the organisms residing in that filter." [4204.]

Various artificial means have been proposed for the purpose, both in this country and America, but none of them has come into general use, and experience seems to show that they are not required. [See Whittaker, 4764.]

"Has any examination been made of the gases in your tank?—I have made several analyses. They are chiefly marsh gas. I have also made attempts at the gas from the filter; several have been made, and we have not, up to now, been able to find any serious diminution in the quantity of oxygen in the body of the filter. [Whittaker, 4804.]

"(Professor Ramsay): Which filter?—In the body of the sprinklcr filter; we have not been ablo to determine any loss in the oxygen, although, as a matter of calculation, the

Aeration of Filters—*continued.*

> quantity of nitrates and the amount of oxidation that takes place—which is measured by the diminution in the oxygen absorbed—the nitrates and the oxygen absorbed are equal to twice the amount of oxygen contained in the interstices of the filter; so that the interstices of the filter must be replaced by entirely fresh air at least twice per day. But seeing that it is difficult to determine any small diminution, it means that the air must have been changed several times in the body of the filter daily." [4805.]

In some cases large quantities of air are forced through the filters by the method adopted for sending on the effluent.

Referring to Mr. Lomax's system of intermittent flushes every twenty minutes, which is in use at Failsworth, Dr. Barwise said:—

> "What impressed me very strongly with regard to this method of applying sewage is, that I went down to the effluent drain and I was able, by striking a match, to prove that the air was displaced by my match being blown out at the bottom of the filter when the sewage was flushed over." [Barwise, 4089.]

In addition to the mechanical effect of the feed in forcing air into the filters there is the action of the bacteria themselves, which, as shown by Mr. Fowler, have so strong an affinity for oxygen that a vacuum of several inches of mercury may be obtained by allowing them to exhaust the air in a closed bulb.

Most trickling filters are so constructed as to secure the freest possible access of air. To this end the side walls of the filter are not, as a rule, built solid, as in the case of contact beds, but are generally formed of honeycombed brickwork, agricultural drain pipes, wooden slats, or even of large pieces of filtering material.

Special attention is also paid to the formation of the filter floor, as in the case of the Salford filter already described (p. 182).

> "The construction of my filter is such that the aërobic microbes may be said to be acting on the sewage practically in the open air, and the length of time of exposure of the sewage to treatment can be regulated to any required extent by merely increasing the depth of the filter. The sides or walls of the filter are so open and porous that air can pass freely through them, though they are capable of supporting

Aeration of Filters—*continued.*

and retaining tho filtering material; and air is distributed throughout the body of the filter by means of air pipes, forming aerating layers at intervals over the whole area. [Ducat, 2185.]

"The main walls of the filter, which may be of any required height, 5 ft., 8 ft., 10 ft., up to 15 ft. or more, will rest on the concrete floor as a foundation, and may be 1 ft. thick, built of agricultural drain pipes, set in cement, having tho necessary masonry pillars or iron framework to strengthen them to support the weight of the filtering material." [2186.]

"What was the construction of your first trickling filter" (at Leeds)?—"It was on lines suggested by Mr. Whittaker, of Accrington, who has since considerably extonded the application of this system of sewage treatment to his own town. The bed is circular, 45 ft. in diameter, 10 ft. deep, and not having to stand any pressure of water, is merely surrounded with wood laths kept together by iron bands." [Harding, 7355.]

"Tell us now about your coarser Whittakor bed.—The construction of this No. 2 bed was as follows: Rows of semi-circular perforated tiles, having a diameter of 18 in., were placed edge to edge, and raised above a slight inclined plane of concrete by means of small brick columns, so that there was a clear air space between the tiles and the concrete floor. Upon this floor was built an octagonal pigeon-holed wall." [7362.]

"It would not be possiblo to make a large surface with a number of sprinklers on it?—I do not think the acration of the interior of a bed liko that would be sufficiont. [Harrison, 14992.]

"Have you any facts to base your opinion upon?—Not with regard to acration. [14993.]

"What is tho diameter, for instance, of a Whittaker?—I should not like to fix on any particular size, but the largest I have had experience of has been 70 ft. That was properly acrated." [14994.]

"No part of the bed to be more than a certain distance from the atmosphere?—I think so." [14996.]

Several of the witnesses, on tho other hand, saw no need to provide for sido aeration.

AERATION OF FILTERS—*continued.*

"(Colonel Harding): Have you at the side of your filters any drain pipes or any means of aeration?—I have experimented with that, sir, but I have abandoned them. [Garfield, 3433.]

"You have found that to artificially bring air to the bottom of the bed was not necessary?—I found that it was better for the air to pass down through the filter itself, as the water was passing on to it in the continual working." [3434.]

"But in this (the Whittaker) filter the sides or circumference were quite open to the air, were they not?—That was so, for the coke was only held together by laths of wood placed three inches apart; but from our experience side aeration seems to be of very little value, as our further experiments will show." [Harding, 7359.]

In the Leeds filter, which is described later (p. 199), side aeration was not provided for.

In connection with the question of assisted aeration, the fact should not be overlooked that during a large part of the year the temperature of the outer air is below that required for the efficient working of the filter bacteria. The introduction at such times of more air than is absolutely necessary will therefore, by lowering the temperature of the filter unnecessarily, be detrimental rather than advantageous.

HEATING OF FILTERS.

Colonel Ducat considered that in the ordinary cold of an English winter artificial means of heating would be required. [2185.] Mr. Whittaker also attached some importance to the heat imparted to the effluent at Accrington by the condensation of the steam used in the pulsometers by which it was pumped. [4823-4.]

In the majority of cases in this country no means of artificial heating have been found necessary, a result which has been due in part to the temperature of the incoming sewage, but partly also to the heat generated by the oxidations which take place in the filter.

In contact bed installations laid down from the writer's plans at Glencoe, near Chicago, and the University of Mount Allison College, at Sackville, New Brunswick, no difficulty has been experienced with temperatures ranging from 10 to 20 degrees below zero Fahrenheit.

Leeds Filter.

Towards the end of the section dealing with preliminary treatment, reference was made to the Leeds filter. The considerations which led up to this new departure are set forth by Colonel Harding as follows:—

"In the case of Leeds, I must say I do not see that there is any necessity for antecedent septic action, and if it proves practicable, as I think it will, to devise an automatic screening apparatus to take off the grosser solids, I think it would be possible to put crude sewage with finely divided solids direct upon a continuous filter, and then have a settling tank at the end of the process, instead of at the beginning, or, if land is available, as it would be probably for the Leeds works, pass it over land for the purpose of mechanically separating—filtering the suspended solids." [7463.]

The filter, which was formed on the old "third triplicate" filter as a foundation, is thus described by Colonel Harding:—

"We left our third triplicate unaltered; we raised its walls with solid brickwork, so that it might hold a depth of 10 feet of coke in all, and to fill up to this depth we just removed the coarse material from beds Nos. 1 and 2. So that in the Leeds bed we used just the same material we were using in the triplicates, except that a little additional material was required to complete the 10 feet. The walls were solid. There was no side aeration whatever. The No. 3 triplicate, which now became the lower part of the Leeds filter, had at the bottom semi-circular perforated pipes, 9 inches diameter, and therefore an air space, but air could only reach it through the 6-inch opening of the outlet valve which remained wide open. At the old surface level of the No. 3 triplicate we laid a + of perforated pipes, and again another 3 feet higher; communicating with these, half bricks were left out in the walls and then loosely put in, so that they could be taken out to obtain samples at different depths of the filter. They have not, in fact, been taken out, so that the aeration is limited to tho 6-inch opening in the bottom outlet valve. [7379.]

"Were you then working on the supposition that aeration is to be avoided?—Oh, no. I quite think that the aeration

Leeds Filter—*continued.*

of the bottom of a trickling filter should be very complete, but we were anxious to try a filter without side aeration at all, for experimental purposes; and we wanted to be able, again for experimental purposes, to regulate the bottom aeration. We were able, for instance, by burning tow in the mouth of the outlet valve to note that there was an inward current, and that it passed upward through the filter—as, indeed, one would expect in a chamber closed at the sides, and with sewage warmer than the atmosphere. [7380.]

"Now, how did the filter work with the coke all in one column as compared with the same material in the triplicate arrangement?—The results were an improvement in the filtrate and better nitrification, due, in my opinion, to more perfect distribution and to the heat of the sewage being better conserved. There was also, of course, an extra foot of depth of coke. I should add we used the same Candy sprinkler as before. [7381.]

"The Leeds bed was started on December 7th, 1900, at a rate of 200 gallons per square yard per twenty-four hours, which on January 21st, 1901, was increased to 400 gallons per square yard. . . . . The sewage we used was exactly the same screened crude sewage as had been put on the triplicates. It contained an average of about 39 grains per gallon of suspended solids. The paper, matches, tea-leaves, fibre, screened off do not usually come into analysis, so that the sewage was in effect crude sewage containing all the finely divided suspended solids." [7382.]

"But could the transformation of suspended solids take place in so short a time (fifteen minutes)?—No. The liquid runs through the filter very fast, but it would seem that the suspended solids take a very much longer time. It is much more difficult to find out what time they do take to pass through, but judging from the time which passes in a new filter before solids begin to come out in the filtrate, I should conclude that in a depth of 9 feet or 10 feet of coarse material the suspended solids would take ten days to a fortnight to work through, and during that time they are exposed not only to bacterial action, but to the digestive processes of large numbers of higher organisms. . . . The bacterial or oxidising action of the trickling filters upon

LEEDS FILTER—*continued.*

dissolved impurities would seem to be extraordinarily rapid and effective, since within a three-minutes' passage there is accomplished a purification of from 80 to 90 per cent." [7384.]

The effluent from this filter contained no less than 8·14 grains per gallon of suspended solids, which it was proposed to settle in tanks, or strain out on a fine filter or land.

CHAPTER XIV.

FILTERING MATERIAL.

Nature of Filtering Material.

One of the most important points to be settled in the design of bacterial filters is the nature and size of the filtering material. It seems to be well established that the function of this material is mainly, if not wholly, mechanical; in other words, it serves rather as a home for the bacteria concerned in the oxidation of the dissolved impurities than as a chemical reagent taking an active part in this process. There is, however, one well-known filtering material, the claims of which are largely based on its chemical composition. The material in question is known as "polarite," and is described by the inventor as follows:—

"We attach very much importance to the substance which is called 'polarite.' . . . . .

"It was an improvement upon Spencer's carbide. Spencer introduced his magnetic porous oxide of iron, but he produced it by introducing foreign matter and by a double process. We produce polarite by a single process, and we claim that there are no impurities in polarite." [Candy, 6999.]

"Previous to this I had been searching for a material containing impalpable pores, and I found in the Bovey Tracey clay basin of South Devon an amorphous deposit which contains very fine silica, so finely divided that it was scarcely perceptible; and we could, by driving off the volatile matters, get a very porous material with which we could obtain marvellous results. The difficulty, however, was, it broke down; it was so friable. Then I saw that another mineral containing carbonate of iron would not break down, and by driving off the carbonic acid we get this microscopic porosity. It is porous in all directions, entirely different to a piece of coke or cinder, in which you get the cells or walls of vitreous matter, whilst in polarite the walls are porous; and the result is, wherever this

Nature of Filtering Material—*continued.*

material is used—used according to our instructions—we get the increased advantage." [7001.]

Alderman Hibbert, referring to the Chorley filters, in which polarite is used, says:—

"And you have come to the conclusion that the polarite is much preferable?—Well, I have come to the conclusion that no works in Lancashire, and I only speak for Lancashire, are getting the same results that we are getting. If they were, we should copy them and alter our own system." [7866.]

"I do not think there is the same purification through clinker or coke as through polarite; I do not think the particles are fine enough. It is undoubtedly mechanical filtration." [7933.]

"(Sir Michael Foster): Does any change take place in the polarite after it has been at work for a long time?—When we had worked our filters five years last October we had occasion to take up one of our filters in order to lead the supply from our sand wash water tank to a well in order that it might be pumped back for re-treatment. We took out each stratum, we found the polarite as sweet as the day it was put in, and we found that there was no disintegration." [Hibbert, 7946.*]

Opinions unfavourable to polarite were expressed by other witnesses.

"I do not believe that polarite has any value whatever." [Dr. Frankland, 9944.]

"After giving the polarite a proper test, and finding it a complete failure, we had to consider some other scheme." [Pickles, 15226.]

See also 519, 577, 833, 3794, 4759 (p. 209), 7875 *et seq.*, 7930.

Even if further experience and investigation should confirm the opinion now generally held as to the absence of any initial chemical reaction between the filtering material and the effluent, it does not necessarily follow that the chemical composition of the former is a matter of complete indifference.

It has been suggested, in view of the steady production of nitrous and nitric acids which goes on in a bacterial filter, and the inhibiting effect which acids are known to exert on nitrifying bacteria [see Ward, 2751-2756], that the filtering material

Nature of Filtering Material—*continued.*

should contain some basic substance, so as to neutralise the acid as fast as it is formed. With this in view, comparative experiments were carried out by Mr. E. Brooke Pike, chemist in charge of the Barking outfall works, with filters filled with ragstone and coke respectively. "The outcome of these experiments" (as reported by Dr. Houston) "seemed to be that the ragstone-coke beds (*sic*) did encourage the growth of the nitrifying germs (as evidenced by an increased production of oxidised nitrogen), but that the effluents, as regards the removal of dissolved oxidisable and putrescible matter, were not so satisfactory from the ragstone as from the coke beds." [L. C. C., Third Report, p. 77.]

A similar suggestion was made by Mr. Cameron about seven years ago, and was tested by the writer by the construction of three small experimental filters; one filled wholly with clinker and the other two with clinker and limestone chippings in different proportions. The filtrates were tested only for nitrates, the amount of which was found to be greatest in those from the all-clinker filter, and least in those from the filter which contained the greatest proportion of limestone. It may be added that the stone used was not a freestone, but a dense limestone from South Devon.

The explanation of these negative results probably lies in the fact that the sewage dealt with in both cases was already alkaline, a condition which, in the absence of acid wastes from manufactories, obtains in the large majority of sewages.

The materials which have been most largely used for filling bacteria beds are coke, clinker, coal, and burnt clay.

Several of the witnesses described their experience with these and other materials, some of them also handing in the results of comparative tests conducted under more or less similar conditions.

Most of the materials which have been used have one feature in common, namely, that they are in some degree porous. The importance of this quality was referred to by Mr. Ward in his examination by Sir Richard Thorne :—

> "Just now you were speaking of particles of a filter being coated with organisms, and, of course, this coating with organisms helps in the bacterial processes. Have you any opinion at all as to whether one or another material which can be coated in that way helps in the process or retards it?

NATURE OF FILTERING MATERIAL—*continued.*

Is it merely a mechanical coating, and does it not matter what the material is, or does the material itself have an influence upon the power of the organisms to deal with sewage?—As an opinion, I think I should express it as follows: that if the material on which the coating is spread increases the surface—that is to say, if it is a coarser porous material—I should expect the action to be much greater than if it is a non-porous material with less surface; but if the substratum has any other importance than as a support to the bacterium, I know nothing about that, and it would be a question quite outside bacteriology." [Ward, 2757.]

Colonel Ducat mentions some good nitrifications obtained with pebbles, and when asked whether the smooth surfaces of these involved "the washing away of the bacterial organisms," replied:—

"If you think of the size of the microbes, and put a pebble under a microscope, you will see it is very rough. It does not house so many microbes—I think that is the weak point—as a piece of clinker, which, of course, is full of large holes, but the roughness of the pobble is quite sufficient to house an immense number." [2233.]

Mr. Cameron, in reply to a question as to the principle that lies at the root of the efficacy of different materials, said:—

"I think coal when broken cubically, with fine, straight, smooth surfaces, or a spar, gives, in my opinion, the ideal surface for filtration. From the small experiments I have tried I have got very good results from smooth surfaces laid dead level, that could be flushed and semi-dried alternately. The sewage coming into contact with surface had a very high purifying effect upon it. And I think that the filtrant that will give these circumstances, without containing any little caves that will hold the water, is the filtrant that gives the best filtrate. [D. Cameron, 2090.]

"You think it is more the character of the surfaces of each individual element, so to speak, in the filter, rather than the intimate nature, the character, the porosity of the particle itself?—I think the filtrant acts purely mechanically; you simply require to produce a surface for the water to flow over. I believe greatly in the uniformity of the material." [2091.]

Nature of Filtering Material—*continued.*

Colonel Harding was also of opinion that porosity was not very important. [See 7221.] He explained this by adding,

> "I think with pieces of coke, which is very porous, the pores are permanently filled with liquid, and the action is very much the same as that of the surface of a rounded pebble." [7223.]

> "I think equally sized gravel would do very well." [7225.]

The witness does not attach much importance to the large extension of surface which porosity confers, and which would apparently enable the more porous material to support a much larger bacterial population than the other. It has been pointed out that a material which is not sensibly porous, such as the pebbles referred to by Colonel Ducat, may yet be sufficiently so to harbour large numbers of organisms; but with a dense material it would seem doubtful whether diffusion could take place so freely as to afford an ample food supply to the bacteria, and remove their waste products as fast as they are formed.

The results of comparative experiments with different materials were adduced by many of the witnesses.

> "Several experiments were made to find out which was the best filtrant, determinations being made by estimating the nitrates in the filtrate, and the best results were obtained from the furnace clinker." [D. Cameron, 1873.]

Mr. Dibdin, "in conjunction with Mr. Thudichum, made a special series of experiments with coke, coal and glass." He gives figures showing that the results obtained from the use of coke breeze were greatly superior to those produced by coal or glass:—

> "Taking the impurity in the coke-breeze effluent as unity, the following ratios are arrived at:—

	Coke.	Coal.	Glass.
Free ammonia	1·00	1·55	1·75
Albuminoid ammonia	1·00	1·72	2·06
Oxygen absorbed	1·00	1·60	1·65

NATURE OF FILTERING MATERIAL—*continued.*

"In this series the superiority of the coke breeze is plainly demonstrated, every possible care having been taken to ensure exactly similar conditions for all three beds.

"The experiments regarding water capacity also placed coke first, the positions of glass and coal, however, being reversed from those shown in the table of quality. After many measurements, extending over seventy-two fillings of each bed, the water capacities were found to be as follows:—

Coke	40·4	per cent. of normal cubic contents.
Glass	39·0	,, ,, ,,
Coal	29·9	,, ,, ,,

"In these experiments, therefore, the coke did not only produce a better result, but with the same total volume of bed purified more sewage, as follows:—

	Sewage purified with Coke being taken at 100;		
then	,, ,,	Glass equals	96·4
and	,, ,,	Coal ,,	74·1

"Put into other words, four acres of coal filter of a given depth would be required to treat the sewage which could be dealt with by three acres of coke breeze of the same depth." [Dibdin, 2170.]

Mr. Dibdin conducted another series of experiments with different materials, the results from which and his conclusions thereon are as follows:—

Extent of Purification effected.

"The following table shews the extent of the purification effected, as indicated by the reduction in oxidisable organic matter in solution:—

Burnt ballast	43·3	per cent.
Sand (1st portion of compound filter)	46·6	,,
Pea ballast	52·3	,,
Proprietary article and sand combined	61·6	,,
Coke breeze	62·2	,,

"From the results obtained, it appeared that a considerable amount of purification could be effected by any filtering material, the desiderata evidently being porosity and consequent power of re-absorbing atmospheric oxygen. For foul waters sand proved too fine, whilst the burnt ballast used was too coarse. Coke breeze seemed to unite the necessary

Nature of Filtering Material—*continued.*

qualifications, and as it is also a cheap material it was selected for a further trial on a large scale. There can be little doubt, however, that the question of cost of material should be allowed to decide what should be used for a filter in any given place, since burnt ballast or gravel may be made much more efficient by using a greater depth of more finely granulated material combined with a slower rate. The proprietary filter excelled the coke breeze only in appearance, the actual purification not being quite so much, whilst the cost is prohibitory." [*Interim Report*, vol. II., p. 123.]

"Dr. A. Bostock Hill, County Analyst, Birmingham, concludes a paper which he read on 'Filtration of Sewage through Coal,' at the Congress of the Sanitary Institute in 1897, with the following:—'I submit, therefore, that in coal we have a filtering medium which produces a result far better than that claimed for other media. It is superior to coke breeze or ballast, in that it has at once a chemical action, and its purifying power is marked from the first day it is used, although a still better result is obtained after a period of two or three months' use. The medium is cheap and easily obtained.'" [Garfield, *Interim Report*, vol. II., p. 196.]

Six years later Dr. Bostock Hill still retained his preference for coal, as will be seen from the following extract from his remarks at the opening of the discussion on "Modern Methods of Treating Sewage" at the Provincial Sessional Meeting of the Sanitary Institute held at Birmingham on 26th September, 1903:—

"As regards the filtering material, though good results can be obtained with almost any hard material, still I believe that coal (which I was one of the first to introduce to public notice) is still the best. It produces at once an effluent far better than any other material, and from the experience that I have had of the Lichfield works now for many years, it continually produced an effluent of high-class quality. Granite chippings are also excellent, and the points which I believe to be of the most importance are that the particles should be hard, angular, fairly smooth, and not liable to break down. Coke breeze, which has perhaps been used more than any other, I do not consider to be particularly good, but it has been shown that excellent

NATURE OF FILTERING MATERIAL—*continued.*

results have been obtained from broken stone and also from broken saggers in the potteries, where, of course, they are obtainable practically for nothing." [*Journal of Sanitary Institute*, vol. XXIV., p. 839.]

Sir Henry Roscoe gives a table showing the average results obtained from Manchester precipitated effluent with small experimental filters of cinder and coke respectively, which he sums up as follows:—

Percentage Purifications.

	Albuminoid ammonia.	Oxygen absorbed.	
		4 hours test.	3 mins. test.
Cinder filtration	70·5	65·8	62·6
Coke	65·5	59·9	55·7

[*Interim Report*, vol. II., p. 206.]

Dr. Barwise refers to some comparative experiments made with coal, coke, and destructor breeze at Buxton:—

"The coal filter reduces the organic ammonia 75·6 per cent., the coke 51 per cent., and the destructor breeze 55 per cent." [4030.]

Dr. Barwise adds:—

"I should say that if the coal does act better than other material that has yet been tried, it is because it has a clean fracture; it has no *cul de sac* for stagnant air to remain in, that it is washed free from dust, and is of such a size that the air can pass away into every part of the filter when it is drained dry." [4032.]

"Our chemist, Mr. Barnes, was instructed by the Board to perform certain experiments—to put down small experimental filters. There were three put down. One was an ordinary polarite bed, another was a sand-filter, and another was a clinker—a small clinker-filter. The precipitated effluent was passed upon these, and Mr. Barnes presented his report to the Board. That report clearly proved that we were getting equally good results with clinkers as we could with polarite." [Whittaker, 4759.]

"The other two pairs of beds (Nos. 3 and 4 and Nos. 5 and 6) were filled with clinker from our destructors. This material was thought to be very cheap, as it could be had for nothing: but as it is produced the material takes the form of slabs, and considerable cost is incurred in breaking it up and in sorting it, so that there is little, if any, advantage over coke in regard to cost. [Harding, 7048.]

"Were you able to judge from the results as to the relative value of coke and clinker as materials for beds?—Well, we found that our clinker-beds never reached the analytical results of the first pair of coke-beds. I do not think, however, that this was so much due to the material as to other circumstances. The coarse coke-bed was 5 feet deep, and the fine bed 6 feet deep, while the clinker-beds were only 3 feet deep. The coke-beds had also been better under-drained than the clinker-beds. I have seen good results from various materials, and I do not see why equally good results should not be obtained from clinker or from coke if the materials are used under equal conditions as to depth of beds and size of material." [7049.]

A comparative experiment with clinker and gravel is described on pp. 219 *et seq.*

Durability of Filtering Material.

A consideration of vital importance in the selection of a filtering material is that as to its durability or otherwise.

Burnt clay, for instance, which was formerly in considerable favour owing to its cheapness in certain localities, has shown itself liable to disintegrate in use. This tendency has already been referred to in connection with artificial filters formed from clay land. [See pp. 149, 150.] Mr. Dibdin, who was one of the first to point out how, in a clay country, filters might be made at low cost by burning and returning the clay, and who has had a wide experience of filters so made, draws attention in his evidence to the perishability of this material. Replying to Professor Foster, with regard to the presence in his filter of forms of life other than the ordinary bacterial organisms, he mentions the larvæ of a little white fly which is often seen in fields, and goes on to say—

"I found they were one of the most active agents in

Durability of Filtering Material—*continued.*

causing the bed to disintegrate (the particles of the bed to disintegrate) when it was made of burnt ballast, because you know that the particles of burnt clay will havo cracks in them in all directions, and these larvæ will travel into the cracks and take up their abode thero, and after a timo the particlo will soften and easily come apart; and that is one reason that, although burnt clay may be very cheap at the start, it is a question whether in the long run it will be as cheap as, say, coke or flints, if flints will answer equally well, and I havo found granito and slate to answer very well." [Dibdin, 3881.]

Colonel Harding, in a passage already quoted, says that "burnt ballast is very liable to reduction." [7063.] The same tendency was observed by Mr. Haworth at Sheffield, who said,

"We have not analysed the effluents from the ballast beds systematically lately, because the ballast itself broke down and crumbled." [14833.]

It is not generally known that the sewage itself exerts a chemical action on the filtering material, but its tendency to do so is mentioned by Mr. Harrison:—

"Clinker is attacked by the sewage; in fact, on first starting a bed filled with fresh clinker, it has been found that a great deal of solid matter goes into solution, chiefly common salt, I believe, and if this goes on for any period the surface becomes brittle, and pieces fall off, and we have been able to find them in the effluent from the No. 2 Whittaker bed. [Harrison, 7120.]

"Then it is a washing out of the soluble matter of the clinker?—Yes." [7123.]

Colonel Harding mentioned that there was "no apparent change in the material (coke) for a long period, used as trickling beds," but goes on to say:—

"During the week that we used it for contact filtration the effect was very remarkable. We found coke floating on the surface, and we found that it rose and then sank again, and in some parts the surface sank as much as a foot." [7450.]

Mr. Fowler, on being asked by Major-General Carey whether

Durability of Filtering Material—*continued.*

he had "formed any opinion as to the life of filtering material, say clinker or coke," replied—

> "I think it may go on almost indefinitely. As I say, I have visited this filter at Clifton Junction and taken samples from that, and the coke was perfectly hard, and after five years the material in the Roscoe filters is as hard as ever. It shows no sign of disintegration except at the top, where it has been forked and disturbed to a considerable extent." [8505.]

Dr. Frankland, however, whether from experience or as a matter of caution, when asked by the same Commissioner whether "the possible renewal of the filtering material would have to be taken into consideration during, say, a period of ten years?" replied "It will have to be taken into consideration."

At the Birmingham meeting of the Sanitary Institute already referred to, Dr. Barwise gave a strong caution with regard to the use of iron slag:—

> "They had been trying slag from iron works in his country, and he would like to warn any engineers who might be about to put down filters, that this was a very dangerous material to use. It contained a large amount of carbonate of lime which was soluble in the effluent from septic tanks. He had seen filters made of this material rapidly break down." [*Journal San. Inst.*, vol. XXIV., p. 854.]

Hardness and toughness are qualities of some importance in a filtering material, as in their absence the weight of the upper layers is liable to crush the material in the bottom of the bed, especially if it is deep. [See Harding, 7214.]

On a review of the whole of the evidence on the subject, there appears to be little doubt that, taken all in all, ordinary hard clinker is in most cases the best thing to use. In many districts this can be obtained in almost unlimited quantities; in others it cannot be procured except at great cost for cartage. It is therefore reassuring to know the opinion arrived at by Dr. Frankland:—

> "Well, in every place there is some local material which may be used. For instance, my attention was called the other day at Burslem to a material which they employ with

great success. It is the 'saggers' from the potteries. It is a magnificent material for sewage filters; it is very porous, very hard, and I should think it is superior to clinkers, and an unlimited quantity of it is available. I think with a little ingenuity probably in any place a local material can be adapted to the purpose." [10067.]

See also 3932, 7063, 7118.

The material mentioned by Dr. Frankland in the foregoing answer was used by Messrs. Willcox and Raikes in some large experimental filters which they laid down at Hanley. These filters form the subject of a report by the County Medical Officer of Health, to which reference has already been made.

Size of Filtering Material.

In the discussion on a paper by Professor A. Bostock Hill, M.D., D.P.H., F.I.C., and Mr. Joseph Garfield, Assoc.M.Inst. C.E., read at the Southampton Congress of the Sanitary Institute in 1899, entitled "Some further Experiments and Results in Bacteriological Treatment of Sewage, with a special reference to Filtration through Coal," the writer joined issue with the writers of the paper when they attributed the excellence of the results obtained to the nature of the material used. He expressed the opinion, in which subsequent speakers concurred, that these results were due rather to the skill and judgment with which the material was graded than to its nature or composition.

The question of the best size for filtering material has been referred to in some of the foregoing answers, and is more particularly dealt with in those which follow.

Since the function of a filtering material is to furnish a home for the bacteria which effect the purification of the sewage, it would seem desirable that it should have within a given space the greatest possible amount of surface for them to collect on, in other words, that a fine small-grained material, other things being equal, will be more effective than a coarser one. A limit, however, is placed to the fineness of the material by capillary attraction, which holds the interstices of a fine filter permanently full of water. Sand is in many respects an ideal filtering material, but its interstices are so fine as to render it liable to chokage. Mr. Alderman Hibbert, however, states that "with an effluent almost completely free from suspended solids" he is

Size of Filtering Material—*continued.*

"able to filter through a fine material like sand." [7916.] And Mr. Harrison, referring to the final filtration of the effluent from the Leeds filter, which contained large quantities of suspended matter, said that it was possible to pass it through a shallow filter, apparently of fine material, at the rate of 2,000,000 gallons per acre per day. [15082.]

The material used by Mr. Cameron at Exeter was passed through a ½-inch screen and rejected by a ⅛-inch screen. [1873.]

> "Having regard to these various results, it is evident that the question of efficiency of a material resolves itself into the character of its surface: thus coal, &c., presents a minimum surface per unit area, whilst coke may be taken as affording a maximum surface for the same area.
>
> "The size of the grain which has been found to be most suitable for the coarse beds is that which will pass, say, a 4-inch mesh and be rejected by a ½-inch mesh, *i.e.*, ordinary coarse coke or the coarsest burnt ballast. For the fine beds, that which has passed a ½-inch mesh or, better still, a ⅜-inch mesh, and been rejected by a 1-16th inch mesh to remove dust, which would otherwise prevent the proper aeration of the bed in consequence of its holding the water by capillary attraction." [Dibdin, 2170.]
>
> "This filtering material must be riddled or screened to the sizes required, viz.:—About ½ to ¼ inch for the upper part of the filter, and about ⅛ inch for the bulk of it, with stuff about 1 inch in size for the drainage layer at the bottom of the filter, and for the aerating layers as filling between the air pipes. No very fine-grained material for mechanical screening of the sewage is necessary at all." [Ducat, 2186.]
>
> "The depth of filtering media should be 5 feet where possible. The whole of the coal used (except a little over and about the under drains) will pass a 3-16 inch mesh. This is divided into two sizes, which I call ⅛-inch cubes and 1-16 inch cubes. The fine dust and dirt being removed, the 1-16 inch cubes form the top layer of the filter." [Garfield, 3411.]
>
> "It is also essential that beds of this character" (bacteria beds) "should be as near as possible of a uniform composition throughout, and not made, as they have been, of coarser

Size of Filtering Material—*continued.*

material at the bottom and finer at the top, like a controlled filter." [Latham, 4505.]

"I have tried ordinary ballast, sandstone and granite chippings. [Whittaker, 4863.]

"(Professor Foster): With what result?—We find it is best to have something large; something about $1\frac{1}{2}$ inches or 2 inches, and coke is the material which gives you the size best. It is the size that determines it, not the nature of the material. [4865.]

"Have you tried finer material at all?—With the finer material the flow at which capillary attraction begins to work is so small and you cease to have the air passages; you must have the passages for free films." [4856.]

"To this end the filtering medium, the composition is immaterial, is of so coarse a grade—2 to 3 inches—as to preclude the possibility of coalescence of the liquid adhering to adjacent particles." [Stoddart, *Interim Report*, vol. II., pp. 290, 291.]

"And what is the nature of the material you are proposing to use?—We shall use very rough material over the drain pipes; the bulk of the material will be such as is retained by $\frac{1}{8}$-inch mesh; that is to say, practically ordinary cinders with anything below $\frac{1}{8}$-inch mesh screened out; the whole thoroughly mixed, and then we shall have about 6 inches of screenings on the top." [Fowler, 5649.]

"I should like to ask Mr. Whittaker another question. You think it necessary, working filters on this system, to use very coarse material?—Yes, not smaller than 2 inches." [Whittaker, 5838.]

The trickling filters at Reigate are thus described:—

"The circular coarse sprinkler bacterial bed is 21 feet diameter, giving a working area of 38 yards; this bed is 3 ft. 9 in. deep, and contains the following layers of broken bricks and clinkers, viz.:—1 ft. 9 in. of 3 in. to $1\frac{1}{2}$ in., 1 ft. 6in. of $1\frac{1}{2}$ in. to $\frac{3}{4}$ in., and between rows of land drain pipes 6 in. of clinker 3 in. to $1\frac{1}{2}$ in. . . . .

"The circular polarite fine sprinkler bacterial oxidation bed is 24 ft. in diameter, giving a working area of 50 sq. yds. This bed is 3 ft. 6 in. deep, and contains the following layers of broken bricks and clinkers and polarite, viz.:—9-in. layer of a size $\frac{3}{4}$ in. to $\frac{1}{2}$ in.; 9 in. of size $\frac{1}{2}$ in.

Size of Filtering Material—*continued.*

to 3-16th in.; 1 ft. 6 in. of a size ½ in. to 3-16 in., which includes the 3-in. layer of polarite; 6 in. of a size 1 in. to ½ in. resting upon the brick channels." [Candy, 7033.]

"What material did you use for the beds" (at Leeds)? —"The first pair, Nos. 1 and 2, were filled with gas coke, which for the coarse bed was larger than 3 inches, and for tho fine bed was from 1½ in. to ¼ in. . . . . The fine beds of these two pairs, viz., Nos. 4 and 6, were both filled with clinker ½ in. to – in. (*sic*); but No. 3 coarse bed was filled with clinker 1 in. to ½ in.; while No. 5 was larger size, viz., 2 in. to 1 in." [Harding, 7048.]

"The grading of the material seems to me to be very necessary. The material should be of equal size. If you use material of unequal size on a contact bed, the effect of filling and emptying is by gradual movement of the material to fit smaller pieces into spaces between larger, and so to bring about consolidation and consequently reduction of capacity. I look upon it as a most important thing that in a contact bed, or in any filter bed, the material should be of equal size. If the material is of equal size I believe the capacity will be the same whether the size be large or small." [7166.]

"I should add that Mr. Whittaker attributed the bad result of this filter to our having used clinker too small, viz., from 3 in. to 1 in." [7357.]

Compare :—

"(Major-General Carey): Does the fine material account for the superiority of the analyses of the Ducat filter, on p. 29, over the Whittaker filter?—It does undoubtedly account for the admirable result which we get on the Ducat bed, when it is working well." [Harding, 7406-7.]

"In making the bed" (at Manchester), "we first of all collect by hand the rough big pieces of clinker which fall to the bottom of the tip. You always find that the big pieces fall to the bottom, and those we take to pile over the drains to improve the drainage. Then the remainder is put through a screen of about ⅜-in. mesh. Practically, that would retain a good deal which is below ⅜ in., but everything which passes that screen is put on the top, or else is used for making concrete." [Fowler, 8543.]

SIZE OF FILTERING MATERIAL—*continued.*

"We have also directed our attention to the grading of the material in the bacterial beds, and are of opinion that the materials generally employed are too coarse. In commencing our experiments we used a coarse upper bed, the clinkers passing a 3-in. sieve, and being rejected by a 1-in. mesh. Being dissatisfied with the performance of this bed we subsequently altered the grade, using clinker which passed a $\frac{3}{4}$-in. and was rejected by a $\frac{1}{8}$-in. mesh." [Dr. Frankland, 9927.]

"When we constructed the first and second contact beds we thought we could not get material fine enough. Now we find that is a mistake, and we find that the clogging is partly due to that." [Pickles, 15314.]

The cinders used in the Salford filters are—

"Of a size that will pass between holes of 3-16ths of an inch and $\frac{3}{4}$ of an inch diameter." [Corbett, 15438.]

"The use of ordinary gas coke, in pieces about the size of walnuts, seems to be attended with the following advantages, as compared with the use of smaller coke. The larger coke enables the bed to hold a larger volume of sewage. The beds now in use had an original capacity for sewage which was nearly equal to the volume of the coke which they contained, in place of only 20 or 30 per cent. of that volume, as is shown by beds containing smaller coke. The use of the larger coke also allows the beds to be more rapidly filled and emptied, and to be more completely emptied and aerated." [*L.C.C. Second Report*, p. 6.]

"As regards the size of the particles, I believe that, speaking generally, a size of about half an inch, with a few inches of fine material on the top of the filter, gives the most satisfactory results." [Dr. A. Bostock Hill, *Jour. San. Inst.*, vol. XXIV., p. 839.]

One of the most important contributions which have yet been made to the study of this question is Dr. Reid's Hanley Report, in which he says—

"We also knew that broken saggers, a waste mineral which is plentiful in the pottery towns of North Staffordshire, formed a good filtering medium, being very hard and non-friable, but we had not quite determined the size of particles best suited for such filters. . . . .

SIZE OF FILTERING MATERIAL—*continued.*

"In order to determine what sized filter particles gave the best results, the filters were divided into sections differing as regards size of particles, and the effluent pipes were so arranged as to allow of distinct samples from each section being collected for analysis. The circular filter was thus divided into four, and the rectangular into two sections, the size of particles from below upwards being as follows:—

CIRCULAR FILTER.

Sect.

I.—6 in.=2½ in. to 1½ in.; 3 in.=1½ in. to ½ in.; 3 ft. 9 in.=3/16 in. to ⅛ in. particles.

II.—6 in.=2½ in. to 1½ in.; 3 in.=1½ in. to ½ in.; 3 ft. 9 in.=½ in. to ⅛ in. particles.

III.—9 in.=2½ in. to 1½ in.; 3 ft. 9 in.=½ in. to ¼ in. particles.

IV.—9 in.=2½ in. to 1½ in.; 3 ft. 9 in.=1½ in. to ½ in. particles.

RECTANGULAR FILTER.

I.—1 ft.=1½ in. to ½ in.; 3 ft. 6 in.=3/16 in. to ⅛ in. particles.

II.—1 ft.=1½ in. to ½ in.; 3 ft. 6 in.=½ in. to ⅛ in. particles.

"It will be noticed that Sections I. and II. in both cases correspond as regards size of particles in the body of the filter. The object of this was to allow a legitimate comparison being made between the results of two filters worked under identical conditions, and differing only in the mechanism for distributing the sewage.

"With reference to the routine working of the filters, I may mention that, with the exception of a temporary waterlogging of the large-grain section of the circular filter (1½ in. to ½ in. particles), an occurrence which was corrected by a short period of rest, no trouble was experienced. That this occurrence should have happened in the case of the large-grain section only, confirms the accuracy of the opinion I formed years ago, namely, that it is desirable to reduce the size of particles in such filters to an extent which is compatible with thorough aeration." [*Hanley Report*, pp. 2, 4.]

From Dr. Reid's analytical tables, which are given on p. 237, it will be seen that the size of the material has a marked influence on the purification effected, the finest material giving much better results than that of coarser grade. On this point, however, Dr. Reid makes the following significant observation :—

> "In this connection, however, the question of cost has to be considered. The crushing of the filtering material into very fine particles adds to the cost of construction, and, bearing this in mind, I have come to the conclusion, in view of the comparative results and having regard to efficiency and economy, that the Corporation of Hanley would be wise to make use of particles of the same size as those forming the body of Section III. of the circular filter, namely, $\frac{1}{2}$ in. to $\frac{1}{4}$ in. With this grade of material, however, it would be wise to protect the filter by forming the top layer, to the depth of about 9 to 12 inches, of $\frac{1}{8}$ in. particles." [*Ib.* p. 9.]

Experiments by Mr. G. H. Martin.

Some interesting information on this and cognate points is furnished by a Report made on 3rd Feb., 1897, by Mr. G. H. Martin, M.A., F.C.S., to the writer and his colleagues, which is now published for the first time :—

> "During the latter part of December, 1896, and in January, 1897, I carried out a series of experiments at Belle Isle with a view to ascertaining the relative values of different filtering materials and the effect on the filtrate of the conditions under which the filters were worked.
>
> In some cases my observations were made on the permanent filters, but for experimental purposes three test filters were set up near the south end of the St. Leonard's tank at Belle Isle, and numbered 1, 2 and 3. No. 1 was filled with clinker, and had been used previously for filtration ; it had since had a long rest. No. 2 was filled with coarse gravel, and No. 3 with fine gravel, the material in each case being previously washed with river-water in order to free it, as far as possible, from dirt. The filters measured roughly 1 foot square by 3 feet deep.

Experiments by Mr. G. H. Martin—*continued.*

I made a rough determination of the amount of liquid adhering to the filtering material after the main body of tho filtrate had passed out, and found that about five-sixths of tho contents were immediately discharged, the remaining sixth draining off slowly.

In nearly every instance the quantity of nitrogen as nitrates found in the filtrate was taken as the measure of the efficiency of the filter. This quantity was estimated by the amount of indigo solution which 25 c.c. of the filtrate, when mixed with twice its volume of concentrated sulphuric acid, would decolourise.

The results obtained are summarised under their respective headings: all the results are calculated in parts per 100,000.

The temperature throughout the whole series of experiments was low, and in all, except those of the first series, it was frequently many degrees below zero (Centigrade).

1. *Comparison between the Filtering Power of Clinker and Fine and Coarse Gravel.*

In this investigation all three test filters were used. The material in filters 2 and 3 was first 'seeded' by passing filtrate from the permanent filters through them a few times before filling them with effluent from the tank. They were filled in succession with this effluent, collected at the V of the gauge-well twice a day as a rule, viz., at 9 a.m. and 2 p.m., and discharged about 12 noon and 5 p.m. These periods varied a great deal, but were always the same for all threo filters, so that the results are quite comparable.

As will be seen hereafter, the nitrates in the filtrate at different stages of the discharge varied considerably. For the sake of comparison, the sample tested was taken after about 1 gallon had been drawn off.

EXPERIMENTS BY MR. G. H. MARTIN—*continued.*

Comparison of Filtering Materials—continued.

Nitrogen as Nitrates in Parts per 100,000.

Filter Material.	No. 1. Clinker.	No. 2. Coarse gravel.	No. 3. Fine gravel.
1896, December 20....	1·45	·87	·87
,, ,, 21....	1·26	·41	·36
,, ,, 22....	1·00	·14	·14
,, ,, 23....	·90	·03	·02
,, ,, 24....	·62	·03	·06
,, ,, 28....	2·59	·27	·51
,, ,, 29....	1·37	·12	·25
,, ,, 31....	1·37	·04	·22
1897, January 1	1·12	·12	·24
,, ,, 2	0·82	·10	·17
Average	1·25	·21	·28

N.B.—Between December 24th and 28th the filters were filled only once.

From these results it appears that fine gravel has more nitrifying efficiency than coarse gravel; but that clinker is a far better material than either. It must be remembered, however, that the clinker used in these experiments had probably benefited much from its rest after previous use.

2. *Comparison of Samples drawn from Filter No.* 3 *at different depths, at intervals after the filling of the filter.*

These observations were made in order to ascertain first the amount of nitrates present in the effluent at different depths in the filter, and secondly, the effect of time on the amount of nitrates present while the filter remained full.

The samples examined were drawn from the permanent Filter No. 3, at depths of 1, 2, 3, and 4 feet respectively, by means of stop-cocks which had been built in for the purpose. The first set of samples was taken as soon as the filter was full, and other sets were taken at intervals of half an hour, the last set being taken just before the discharge of the filter.

EXPERIMENTS BY MR. G. H. MARTIN—*continued.*

Comparison of Samples from different depths—continued.

Nitrogen as Nitrates in Parts per 100,000.

1897. January 18.	Directly after filling.	½ hour after.	1 hour after.	1½ hours after.	2 hours after.
Depth 1 foot	0·74	0·56	0·71	0·61	0·64
,, 2 feet	1·58	1·50	1·50	1·57	1·79
,, 3 feet	1·78	1·69	1·88	1·81	1·93
,, 4 feet	1·02	1·14	1·27	1·21	1·34
Average	1·28	1·22	1·34	1·30	1·43

Nitrogen as Nitrates in Parts per 100,000.

1897. January 20.	Directly after filling.	½ hour after.	1 hour after.	1½ hours after.	2 hours after.
Depth 1 foot	0·33	0·42	0·29	0·30	0·39
,, 2 feet	1·18	1·15	1·24	1·27	1·29
,, 3 feet	1·43	1·36	1·36	1·39	1·34
,, 4 feet	0·83	0·67	0·76	0·84	0·85
Average	0·94	0·90	0·91	0·95	0·97

In almost every case there is a slight fall in the amount of nitrates at the end of the first half-hour, and in most cases a rise (or no alteration) at the end of the second half-hour, from which point to the time of discharge there is a slight increase in the amount. The results after the third half-hour show more variation.

The total increase in nitrates due to resting full is therefore not large, and falls off when the filter is in continuous work. The increase on January 18th was 11·7 per cent., and on January 20th only 3·2 per cent. The difference might also be due to temperature. January 18th was a sunny day, with a maximum temperature of 72° in the sun; January 20th was cold and bleak, with a fine drizzle.

The results further show that nitrification is more active in the body of the filter than at either the top or the bottom, the 3-feet depth being the best in all cases.

EXPERIMENTS BY MR. G. H. MARTIN—*continued.*

3. *Comparison of Filtrate at various Periods of Discharge.*

These observations are, to a certain extent, supplementary to those already set forth, but while the latter show the variation in the amount of nitrates at different depths in the filter, those now to be considerod show the variation at different periods of the discharge. Generally speaking, the filtrate which is first discharged will come from the lowest part of tho filter, and succeeding portions from the upper layers, but the liquid contained in the larger spaces near the top of the filter will probably make its way to the outlet in advance of the filtrate from the finer interstices lower down.

Nitrogen as Nitrates in Parts per 100,000.

TEST FILTERS, DECEMBER 20TH, 1896.

—	First Drawings.	After Drawing off 1 Gallon.	After Drawing off 2 Gallons.
1. Clinker ...	1·29	1·45	1·67
2. Coarse gravel	·76	·87	1·60
3. Fine gravel..	·97	·87	1·44

LARGE FILTERS.

After discharge.	Filter No. 1, Dec. 21.	Filter No. 5, Jan. 2.	Filter No. 4, Jan. 18.	Filter No. 3, Jan. 21.
5 minutes	1·72	·62	—	·45
10 ,,	2·03	(9 min.) ·56	—	—
15 ,,	2·06	—	1·25	·56
20 ,,	1·67	—	1·13	—
25 ,,	2·12	—	—	—
30 ,,	1·97	—	—	—
35 ,,	1·78	—	—	—

EXPERIMENTS BY MR. G. H. MARTIN—*continued.*
Nitrogen as Nitrates in Parts per 100,000—continued.

FILTER ATTACHED TO EXPERIMENTAL TANK.

2 minutes after discharge..	1·44.
20 ,, ,, ..	1·40.

4. *Comparison of Results of Slow and Quick Discharge.*

Two small filters (2 and 3) were filled with clinker, and the clinker washed several times with filtrate, and the two filters were treated throughout as similarly as possible. After washing they were filled with effluent twice a day, a bucketful being placed in each alternately. The filters were discharged after standing full for two or three hours. No. 2 was discharged slowly each time, and No. 3 at about four times the rate.

(The filtrate from No. 3 always contained a black sediment which looked like soot.)

Samples of the filtrate were tested for nitrates after about 1 gallon had been drawn from each. The results were as follows, and were slightly in favour of the slow discharge. The difference in the results given by the two filters may, however, be due to the dirtier state of the material in filter No. 3:—

Nitrogen as Nitrates in Parts per 100,000.

1897. January ..	18	19	20	21	22	Average.
No. 2 (slow discharge)..	·52	·44	·20	·21	·16	·31
No. 3 (fast discharge)..	·43	·35	·15	·16	·12	·24

EXPERIMENTS BY MR. G. H. MARTIN—*continued.*

5. *Comparison of Successive Discharges before and after a Period of Rest.*

In nearly every instance in which several successive discharges of the same filter have been observed, they show a gradual decrease in the amount of nitrates present. Thus, an inspection of the results in section 1 shows a gradual decrease in the amount of nitrates present in the filtrate for all three filters from December 20th to December 24th, then a sudden rise on December 28th, and again a gradual decline. The rise was no doubt due to the fact that the filters were left empty (except for one filling on December 26th) from December 24th (evening) to December 28th (morning), *i.e.*, for three days.

The gradual falling off during continuous working is also noticeable in the figures given in section 4 in the comparison of slow and quick discharge.

It is also very marked in the results of the experiments on filter No. 3 (see section 2), the quantities of nitrates found in the filtrate on January 20th being distinctly less than those found at corresponding times on January 18th. Each individual result on January 20th was less than the corresponding one on January 18th.*

* [The beneficial influence of an interval of rest was noted also by Dr. Reid in connection with the continuous filters at Hanley, as shown by the following extract from his Report, pp. 7 and 8 :—

"I have also omitted the last records, because it happened that the rectangular filter had been at rest for repairs to the machinery for ten days, and the circular for thirty-six days previous to the collection of these samples, and one naturally would expect the results to be exceptionally good after such periods of rest, an expectation which is very strikingly exemplified by the very high nitric-nitrogen figures in the case of the circular filter effluents."

A. J. M.]

EXPERIMENTS BY MR. G. H. MARTIN—*continued.*

6. * *Comparison of the Amounts of Nitrates in the Effluent from the Permanent and Experimental Tanks before Filtration.*

During these observations a part of the effluent from the permanent tank was passed through the experimental tank, the effluent from which had thus gone through both tanks in succession.

The samples in each case were taken from the far ends of the filter channels.

Nitrogen as Nitrates in Parts per 100,000.

	Permanent Tank.	Experimental Tank.
January 16..............	·23	·20
,, 18..............	·13	·02
,, 19 (morning)	·18	·02
(afternoon) ..	·03	·014
,, 20 (morning)	·08	·005
(afternoon) ..	·035	none
,, 21..............	·056	none
,, 22..............	·035	·007

The quantities of nitrates in the effluent from the experimental tank were so little that it was impossible to estimate them accurately: the above results are, for them, only approximate.

7. *Experiments with the Insolator.*

With a view to finding out what would be the effect on the filtrate of standing in the open air for some hours, a shallow box was placed under the tap of the test filter No. 1 of such a capacity that it just held the liquid contents of the filter. The box was divided transversely by a partition, the top of which was a knife edge, over which the filtrate flowed into the shallower but more extensive receptacle

* This experiment was made with the object of ascertaining the effect of prolonging the tank treatment beyond that afforded by the permanent tank. [A. J. M.]

EXPERIMENTS BY MR. G. H. MARTIN—*continued.*

beneath. Samples were taken from the inlet and outlet ends just after filling the box by the discharge of the filter, and again of the same liquid some hours after.

The temperature during this series of experiments was many degrees below freezing-point as a rule, and the insolator was frozen over hard each morning.

Nitrogen as Nitrates in Parts per 100,000.

January 18.	Filtrate running in at 12 noon	1·56
	Do. from outlet end at 3 p.m.	1·19
	,, ,, 4 p.m.	1·27
January 19.	,, from inlet end at 12 noon	1·02
	Do. from inlet end at 4 p.m.	·77
	,, outlet end at 4 p.m.	·69
January 20.	,, from outlet end at 12 noon	·70
	Do. from outlet end at 2 p.m.	·79
January 21.	,, from outlet end at 11.30 a.m.	1·10
	Do. from outlet end at 4 p.m.	·65
January 22.	,, from outlet end about noon	·95
	Do. from outlet end at 4 p.m.	·74

Thus there was a decrease in the amount of nitrates present in every case except one. The low temperature and absence of sunlight were, no doubt, largely responsible for this.

I have plotted curves for a few of these results; the variations from various causes are thereby rendered very evident." [Report by Mr. G. H. Martin.]

It will be seen that the report deals with a number of other points which arise in working, and to some of which very little attention has yet been paid.

CHAPTER XV.

CONTACT BEDS VERSUS TRICKLING FILTERS.

The question of the comparative merits of the contact and the trickling methods has attracted much attention during the past few years, and it is perhaps not surprising that the preponderance of opinion, from a purely theoretical point of view, has been on the side of the former.

The claims made on behalf of the trickling method are based partly on theoretical and partly on practical grounds.

> "Have you been able to come to a conclusion as to the best way of working artificial filters; whether intermittently or on the principle of a continuous dribbling through the material and a continuous aeration?—I have not had any proper comparative tests, but I am quite satisfied that the continuous dribbling is satisfactory. [Barwise, 4077.]
>
> "And you incline to the view that that is the preferable plan?—I am inclined to that view. I do not hold the view very strongly; I should like that to be the result, because I think it would be cheaper to construct works upon that principle." [4078.]
>
> "The correct method of working is a *continuous* process in the three stages I have indicated; first, of anaërobic liquefaction or hydrolysis; second, of partial aërobic change; third, of full aeration with nitrification. In methods involving a 'resting full' and 'resting empty' period, there is alternate inversion of bacterial action between aërobes and anaërobes, with a disturbance of both, necessitating prolonged periods of rest." [Rideal, 4141.]
>
> "If you will replace the present filter beds at Exeter by some of Scott Moncrieff's trays, or by a Ducat filter, you will get more nitrification, and do away with the resting

COMPARISON OF CONTACT AND TRICKLING FILTERS—*continued.*

period, and work it continuously in the same way as a septic tank works continuously." [4225.]

"It has been generally agreed, since the first report of the Royal Commission on Rivers Pollution, that the sewage filter is essentially an oxidising instrument, the source of the required oxygen being the air. If this be so, it follows that the intermittent filter, as devised by the Royal Commissioners, and still more the type in common use at the present day, must be more or less inefficient, because during a considerable part of the cycle of operations the liquid to be oxidised lies in bulk and by no means in intimate contact with the air.

"It was this consideration which led me to the construction of a continuous filter of small dimensions, by means of which it was clearly demonstrated that not only is a great waste of time involved in pouring liquid in bulk on an oxidising filter, but that the oxidising microbes are greatly debilitated by submergence in a fluid devoid of oxygen, and that aeration of such portions of the filter as may not be waterlogged is much interfered with by the seal formed by even a slight layer of liquid in any part of the filter.

"The period of rest insisted upon in connection with the intermittent filter is therefore only an attempt to remedy the mischief caused by overdosing the filter in the preceding stage . . . . .

"As to the cost of this form of filter, whilst, of course, the distributor increases the expense of erection, this increase is counterbalanced by the simplification in construction, and especially by the absence of walls and foundations, so that the prime cost exceeds by little, if at all, that of the usual type of intermittent filter. As, however, the improved filter does five times the work, it is, in reality, much cheaper; and, in addition to this saving in initial cost, there is to be considered the practical abolition of working expenses.

"I calculate, therefore, that the substitution of the continuous for the intermittent filter represents a saving of not less than 75 to 80 per cent., insures the production of a better effluent of uniform character, and reduces to a minimum the risk of stoppage or interruption of the process of filtration." [Stoddart, *Interim Report*, vol. II., p. 291.]

(See also 2187, 7761.)

COMPARISON OF CONTACT AND TRICKLING FILTERS—*continued.*

The processes involved in the purification of sewage are, however, far too complex, and our knowledge concerning them is too scanty, to render it safe to arrive at conclusions concerning them from *à priori* considerations alone; and in no field of work is it more necessary to remember that "the proof of the pudding is in the eating." In determining the value of any particular method, regard must be paid, not only to the soundness of the principle involved, but also to the readiness or otherwise with which it can be applied to practice.

The considerations which have brought about so wide an adoption of the contact system are chiefly of a practical nature. It is, however, not without warrant from a scientific point of view. The omission of the believers in contact to reply in kind to the sweeping denunciations of this principle which are often indulged in by those who favour the trickling method may easily have led casual observers to lose sight of the strong scientific justification which contact undoubtedly possesses. Reference has already been made (p. 144) to the habit of regarding the work of a filter as consisting wholly or mainly of nitrification. The view held by those who have looked into the subject more closely was well expressed by Dr. Fowler in the course of the discussion on Sewage Disposal which took place at the Sanitary Congress at Bradford in 1903, when he said:—

> "Sanitarians did not yet know enough of the intimate reactions which went forward in continuous filters and contact beds respectively to say always which were to be preferred: for this reason, that the purification of sewage was, he was convinced, not a simple oxidation process. It was much more complex, and the denitrification changes were quite as important in some cases as the nitrification change, and there were other than nitrogenous impurities which they could not leave in the effluent." [*Journal San. Inst.*, vol. XXIV., p. 354.] [See also Dibdin, 3893.]

The importance of the denitrification changes of which Dr. Fowler speaks is recognised also by Dr. Rideal, who refers to them in his book on "Sewage and its Purification," an extract from which is given on pp. 167, 168.

Amount of Purification Effected.

In a comparison of the two methods in question, the amount of purification must first be considered.

Tables were handed in showing the analytical results from a large number of works on both systems. It will suffice here to reproduce a few typical analyses and observations of some of the witnesses on the results from representative works.

Purification effected by Contact Beds.

(Colonel Harding): "Now, what was the purification obtained by the single contact filtration following upon the closed septic tank treatment" (at Manchester)?—"It was very satisfactory. I can give you figures which show that for nine months at any rate out of eighteen we have practically never had a putrefactive sample. We have not always reduced the actual oxygen absorption figure below the limits set us by the Mersey and Irwell Joint Committee, but there has always been a large amount of nitrates present which has been sufficient to oxidise any residual impurity which might be left." [Fowler, 5490.]

"The results have been very good indeed; the effluent from the biological treatment of the Sheffield sewage is one of the best we have had, and consistently good; but I am unable to say as to the length of life of the filters at Sheffield." [Dr. Wilson, 6390.]

"Could you give us any instances of effluents from bacteria beds in your watershed?—We have good results from Oldham. They have the largest area of bacteria beds." [Tatton, 6640.]

"And are those effluents satisfactory that come from the bacteria beds?—Yes, they are perfectly satisfactory; they always come within the limits; they are generally about ·7 or ·8" (oxygen absorbed). [6644.]

"What kind of results did you obtain as regards purification by your double contact filtration?—From experience gained during over three years in treating Leeds sewage on contact beds, it was found that whether dealing with crude sewage, screened sewage, or partially settled sewage, variable but very good effluents could be obtained, much superior to those from lime precipitation. Their chemical analyses gave

results which were generally within the limit of one grain per gallon oxygen absorbed, and ·1 of albuminoid ammonia, limits which have in recent years been accepted by the Lancashire and Yorkshire Rivers Boards as a provisional standard of purity for effluents going into a stream not used for drinking purposes. The following are the average analytical results obtained over long periods, as detailed in the report referred to :—

Average Analyses of Sewage and Effluents from Contact Beds at Leeds.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen Absorbed.	Nitrogen as Nitrates.
Oct. 27, 1898, to Oct. 9, 1899—						
Crude Sewage	117·0	40·7	1·72	·809	8·04	—
Filtrate from Bed No. 1	75·3	11·5	1·098	·318	2·48	—
Filtrate from Bed No. 2	68·4	1·9	·31	·081	·50	·392
Percentage Purification effected by Bed No. 1..	—	71	36	60	69	—
Percentage Purification effected by Beds Nos. 1 and 2	—	95	81	90	93	—
Nov. 1898, to June, 1900—						
Crude Sewage	118·4	42·8	2·02	·964	8·80	—
Filtrate from Bed No. 3	82·3	12·6	0·920	·289	2·07	—
Filtrate from Bed No. 4	73·0	3·3	0·581	·108	·655	·261
Percentage Purification, Bed No. 3	—	70	54	70	76	—
Percentage Purification, Beds Nos. 3 and 4 ...	—	92	71	88	92	—
Mar. 1899, to Nov. 1899—						
Crude Sewage	124·8	46·1	2·05	·997	9·12	—
Filtrate from Bed No. 5	81·9	13·7	1·23	·397	2·91	—
Filtrate from Bed No. 6	71·5	3·3	·666	·141	·790	·127
Percentage Purification, Bed No. 5	—	70	39	60	68	—
Percentage Purification, Beds Nos. 5 and 6......	—	92	67	85	91	—

"These results were obtained notwithstanding the large volume and variety of trade effluents mixed with Leeds sewage." [Harding, 7058.]

The averages of a later series of results, covering the six months ending September, 1902, are given by Mr. Harrison in the evidence accompanying the Commissioners' Third Report.

Averages of Analyses for the Six Months ending September, 1902.

Grains per Gallon.	Free Ammonia.	Albuminoid Ammonia.	Oxygen Absorbed in 4 Hours.
Partially settled sewage	2·82	·560	5·31
Effluent from closed septic tanks	2·05	·377	3·76
Percentage purification effected by septic tanks	27	33	29
Filtrate from Cameron Plant	·718	·107	·504
Percentage purification effected by filters	65	72	87
Crude sewage	2·78	·669	6·64
Effluent from open septic tanks	2·07	·600	5·25
Percentage purification effected by septic tanks	26	10	21
Filtrate from No. 1 Manchester bed ..	1·26	·226	·957
Percentage purification effected by No. 1 bed	39	62	82
Filtrate from No. 2 Manchester bed ..	·379	·065	·331
Percentage purification effected by No. 2 bed	70	71	65

[14912.]

In the experimental coke beds at Crossness,

"Not only has the suspended matter been removed, but the removal of the dissolved oxidisable and putrescible matters of the raw sewage has been secured to the average extent of 51·3 per cent. by the single process, the 4-feet coke bed giving 52·7, and the primary 6-feet coke bed 49·9 per cent. The effluent thus produced remains free from objectionable odour when it is kept in open or in closed vessels, provided the bacteria present in it are not removed or killed by special subsequent treatment. This effluent could therefore produce no offensive smell when it is introduced into the river." [*L.C.C. Second Report*, p. 6.]

The average percentage purifications effected by the "one-acre coke bed" at Barking, together with the amounts of nitrogen

oxidised during the years 1900 and 1901, are given by Dr. Clowes in his Fourth Report to the London County Council, as follows:—

Parts per 100,000.

	Oxygen absorbed in 4 hours at 80° F.		Nitrous N.	Nitric N.
	By the crude liquid. Total putrescible matter.	By the clear liquid. Dissolved putrescible matter.		
1900	85·7	84·3	0·0541	1·0429
1901	85·5	83·7	0·0782	0·9513

Purification effected by Trickling Filters.

"Now, Mr. Whittaker, what kind of results have you obtained in regard to purification by the use of the filters" (at Accrington)?—"The average of a number of analyses has given us in the final effluent 64 per cent. on the tank effluent, and 81 per cent. of purification on the raw sewage. [5791.]

"As measured by what?—By the albuminoid ammonia. [5792.]

"That includes the solids in suspension in the final filtrate?—Yes, everything. [5793.]

"Then what in regard to the oxygen absorbed?—The oxygen absorbed gives 66 per cent. and 81 per cent. [5794.]

"Sixty-six on the tank effluent and 81 on the raw sewage?—Eighty-one on the raw sewage. The 66 per cent. of purification is including all the suspended matter, and 76 per cent. with the suspended matter removed. That gives the amount of suspended matter." [5795.]

"And you find the action of the trickling filters" (at Salford) "upon dissolved impurities to be effective and rapid?—Most thoroughly effective. We have used these filters now for just about ten years experimentally, and our results have always been very good." [Corbett, 15454.]

Very comprehensive tables were put in by Colonel Harding and Mr. Harrison of the analytical results obtained at Leeds. The value of these is twofold. In the first place, they afford a comparison of the working of different systems under more or less parallel conditions; and, secondly, they are averages over long periods, thus avoiding the errors which are inevitable where single sets of samples are relied on.

Average Analyses of Sewage and Effluents from Trickling Filters at Leeds.

Grains per Gallon.	Total solids.	Suspended solids.	Free ammonia.	Alb. ammonia.	Oxygen absorbed (4 hrs. 80° F.).	Nitrogen as nitrates.

WHITTAKER BED No. 1. 9th March, 1899, to 8th May, 1900 (14 months).

Septic tank effluents...............	78·4	13·1	1·80	·434	4·02	—
Filtrate, Whittaker Bed No. 1	69·8	5·6	0·688*	·113*	·684*	·548*
Purification effected on septic effluent	—	57 p.c.	61 p.c.	73 p.c.	83 p.c.	—

* Analysis made after rough settlement of suspended solids.

[7360.]

WHITTAKER BED No. 2. 2nd September, 1899, to 30th June, 1900 (10 months).

Septic tank effluent	78·1	14·4	1·85	·455	4·18	—
Filtrate, Whittaker Bed No. 2	70·7	7·7	·532*	·079*	·590*	·669*
Percentage purification on the septic effluent	—	46 p.c.	71 p.c.	82 p.c.	85 p.c.	—

* Analysed after the rough settlement of suspended solids taken from October 23rd, 1899, to June 30th, 1900.

[7369.]

DUCAT FILTER. 29th March to 30th April, 1900 (1 month).

Sewage	129·7	53·7	2·83	1·09	7·98	—
Filtrate	71·6	nil	1·00	·122	·711	·313
Percentage purification	—	—	65 p.c.	88 p.c.	91 p.c.	—

DUCAT FILTER. 13th June to 7th July, 1900 (3 weeks 3 days).

Sewage	127·9	59·4	2·79	1·07	9·90	—
Filtrate	69·0	trace	·165	·043	·241	·818
Percentage purification	—	100 p.c.	94 p.c.	96 p.c.	97 p.c.	—

[7372.]

AVERAGE ANALYSES—*continued.*

Grains per Gallon.	Total solids.	Suspended solids.	Free ammonia.	Alb. ammonia.	Oxygen absorbed (4 hrs. 80° F.).	Nitrogen as nitrates.
TRIPLICATE BEDS. 26th March to 30th June, 1900 (3 months). Analyses are inclusive of all suspended solids.						
Sewage	123·2	44·2	2·36	1·04	8·90	—
Filtrate from 1st bed	87·6	19·2	1·58	·599	4·37	—
Filtrate from 2nd bed	74·0	7·9	1·15	·430	2·78	—
Filtrate from 3rd bed	71·7	7·7	·828	·297	1·93	·141
Percentage purification	—	82 p.c.	64 p.c.	71 p.c.	78 p.c.	—
[7374.]						
LEEDS FILTER. 13th December, 1900, to 14th January, 1901 (1 month).						
Sewage sent on to bed	103·	34·	2·	·8	7·86	—
Filtrate	68·5	5·7	·272	·107	·85	·434
Purification	—	—	86 p.c.	86 p.c.	89 p.c.	—
[7385.]						

The average results for the half-year ending September, 1902, are also given.

Averages of Analyses for the Six Months ending September, 1902.

Analyses of—	Free Ammonia.	Albuminoid Ammonia.	Oxygen Absorbed in 4 Hours.
Crude sewage (fine screened)	2·33	·643	6·73
Filtrate from Leeds filter (unsettled)	·589	·274	2·42
Percentage purification effected by filter	75	57	64
Effluent from open septic tanks	2·28	·417	4·11
Filtrate from Whittaker Bed (unsettled)	·225	·083	·851
Percentage purification effected by filter	90	80	79
Effluent from open septic tanks (fine screened)	1·93	·383	3·75
Filtrate from Ducat Bed (unsettled)	·483	·115	·961
Percentage purification effected by filter	76	70	74

[14912.]

The results obtained by Dr. Reid in his Hanley experiments are set forth in the following table, which is particularly interesting as showing the quality of the work done by different grades of material.

HANLEY EXPERIMENTS.

Analyses of Sewage and Effluents. Mean Results in Parts per 100,000.

Sample.		Size of particles in body of filter.	No. of samples.	Solids. In solution.	Solids. In suspension.	Solids. Total.	Chlorine.	Free ammonia.	Organic ammonia.	Oxygen absorbed in 4 hrs. at 80° F.	Nitric nitrogen.
Sewage		—	8	125·4	62·9	188·3	8·9	2·109	0·765	3·854	0·00
Septic Tank		—	7	105·3	4·4	109·7	8·7	1·820	0·270	1·725	0·00
Rectangular.	Sect. I.	3/16 in. to 1/8 in.	14	112·0	0·4	112·4	8·5	0·081	0·029	0·273	1·75
	" II.	1/2 in. to 1/8 in.	14	111·9	0·3	112·2	8·3	0·098	0·032	0·278	1·73
Circular.	" I.	3/16 in. to 1/8 in.	13	112·1	0·2	112·3	8·4	0·096	0·025	0·242	1·66
	" II.	1/2 in. to 1/8 in.	13	112·9	1·4	114·3	8·3	0·036	0·029	0·259	1·53
	" III.	1/2 in. to 1/4 in.	13	112·8	0·7	113·5	8·4	0·037	0·030	0·252	1·62
	" IV.	1½ in. to ½ in.	13	113·1	1·7	114·8	8·3	0·119	0·046	0·327	1·62

"In view of previous reports in which the matter has been fully explained, it is unnecessary to go into detail as to the significance of the various figures; I would remind the Committee, however, that the important figures to consider in judging of the degree of purification effected are those showing the reduction of oxygen absorbed and organic ammonia in the effluents compared with the sewage, as well as those showing the extent to which the organic nitrogen of the sewage has undergone oxidation, as indicated by the amount of nitric nitrogen in the effluents. . . .

"Shortly, the conclusion to be drawn from the figures is that in every case the degree of purification which has been effected is excellent. The good quality of the work done exceeds that of any plant of which I have had experience, neither do I know of any published records from similar works which will approach those of Hanley as regards the degree of purification effected. . . .

HANLEY EXPERIMENTS—*continued.*

"It will be seen that treatment in the 'septic' tank effected a purification of 64 per cent. and 62 per cent. in the organic ammonia and oxygen absorbed figures respectively, while as regards the filter effluents these percentages varied from *94 per cent. and *91 per cent. in the case of the large grain section of the circular filter to *97 per cent. and *94 per cent. in the case of the finest grain section, the last-named figures being practically the same in the corresponding section of both filters." [*Hanley Report*, pp. 7, 8.]

The percentage purifications effected by trickling filters in several important works, with other interesting information, and the average annual percentage purifications by various combinations of processes, are given by Mr. Watson in his Birmingham lecture in two valuable tables.

TABLE *showing quantity of Sewage purified by means of Percolation Bacteria Beds at various Places in 24 Hours per Acre of Bed, with average Percentage of Purification on Crude Sewage.*

Name of Town or District.	Time during which the Beds were at Work.	Depth of Bed.	Quantity of Sewage treated in 24 Hours per Acre of Bed.	Average Percentage Purification.	
				Oxygen Absorbed.	Albuminoid Ammonia.
	Years.	Feet.	Gallons.	Per cent.	Per cent.
Leeds	3½	9	1,000,000	95·0	90·0
Accrington	3	8 to 9	1,936,000	90·0	91·3
Birmingham....	½	5	1,000,000	86·3	88·4
Hyde	3	9	2,178,000	85·7	90·0
York	1	6·5	2,129,600	84·5	90·0
Rochdale	2½	9	1,936,000	84·0	84·2

[Birmingham Lecture.]

* These are the *total* purifications by the septic tank and filter, those effected by the latter alone being for the large grain section 83 per cent. and 81 per cent., and for the finest grain section 91 per cent and 86 per cent. respectively. [A. J. M.]

COMPARISON OF PURIFICATION EFFECTED.

TABLE *showing average Annual Percentage of Purification on Crude Sewage, based on Oxygen-absorbed Test, obtained by typical Processes of Sewage Purification at various Places in England.*

Process.	Name of Town.	Percentage of Purification.
Septic tanks and land	Birmingham ..	90
Septic tanks and single contact beds	Birmingham ..	80
	Manchester	75
	Croydon	63·8
Septic tanks and double contact beds	Leeds	95
	Sheffield	87 to 90
	Burnley	87
	Blackburn	75 to 80
	Carlisle	71
Septic tanks and percolation beds....	Leeds	95
	Accrington	90
	Birmingham ..	86·9
	Hyde	85·7
	York	84·5
	Rochdale	84
Chemical precipitation and percolation beds, 5 feet deep	Salford	82
Chemical precipitation and percolation beds, 8 feet deep	Salford	95

[Birmingham Lecture.]

The general character of the results obtained by the two modes of filtration is shown by the following extract from Dr. Fowler's lecture:—

"Thus the percentage purification, either as measured by the oxygen absorbed or by the albuminoid ammonia, gives an excellent idea of the work done. It has, in fact, been argued by Dunbar and Thumm, that if a certain per cent. purification, *e.g.*, 60—65 per cent. of any given tank

Comparison of Purification—*continued.*

effluent, as measured by the Kubel method, after filtration through paper, has been effected by the purification process, the final effluent is non-putrefactive, whatever the absolute numbers may be. This may hold in certain cases, but hardly in all. . . . .

"There can be no doubt that the amount of nitrate appearing in an effluent is the residuum left over after a certain proportion has been employed in oxidising carbonaceous impurities. This is especially so in the case of the contact bed. If the material of a contact bed is washed out after rest with ordinary town's water, much more nitrate will be obtained in solution than if, say, septic tank effluent were employed. This denitrification change is no doubt necessary for the effective oxidation of many substances, *e.g.*, cellulose. In the case of the contact bed the two changes, nitrification and denitrification, take place alternately, and possibly also simultaneously in the same bed; and consequently after double contact an effluent is obtained where both carbonaceous and nitrogenous organic matters have been well oxidised.

"In the case of continuous filters, at any rate those of the more open kind, the ammonia is rapidly oxidised to nitric acid, but the conditions do not seem so favourable to carbon oxidation; therefore these filtrates often have a rather high oxygen absorption and albuminoid ammonia, and incompletely oxidised organic suspended matter passes through and has to be strained out or settled. During the straining process some amount of denitrification takes place, and the final effluent, though containing less nitrate, is of greater general purity. It is here that the sequence of changes in biological filters appears to be different from that taking place during direct oxidation in mixtures of sewage or effluent with oxygenated water. . . . .

"If a good supply of nitrate is present the effluent will rarely, if ever, putrefy on incubation, the oxygen of the nitrate being sufficient to oxidise the residual impurity; in any case the degree of putrefaction indicated by the increase in the three minutes' oxygen absorption test before and after incubation will be less." [Manchester Lecture, pp. 16, 17.]

In Mr. Stoddart's opening statement (*Interim Report*, vol. II., p. 291) he claims that "the soundness of these views" (as to the

COMPARISON OF PURIFICATION—*continued.*

mistakenness of the intermittent filter and the superiority of his own) "is finally proved by the success that has attended their application upon a larger scale."

Mr. Stoddart's appeal to the ordeal of practical working has recently been answered by the publication of a report by Dr. Letts, in which he details the results of some comparative experiments with filters:—

"*Experiments with a closed Septic Tank and double Contact Beds, and also on the Treatment of the Septic Tank Effluent by a Stoddart Filter.*

"The experimental plant consisted of a septic tank in conjunction with two new sets of small contact beds, and also of a small continuous filter on Stoddart's system and provided with his sprinkler. Part of the effluent from the septic tank was submitted to treatment on the contact beds, while another part was treated by the Stoddart filter. . . . .

"The contact beds were each 19 feet in length, 11 feet wide, and 2 feet 6 inches deep. The upper series contained fragments of brick, which passed through a 1½-inch mesh, but were rejected by a ½-inch mesh. The lower series contained fragments of the same material but of finer grade, *i.e.*, such as passed through a ½-inch mesh but were rejected by a ⅛-inch mesh.

"The working cycle of this installation was as follows:—

Resting in septic tank	....	12 hours.
ditto upper contact beds	..	3 do.
ditto lower ditto	..	3 do.

"The Stoddart filter consisted of a built-up heap of 'destructor' clinker, each block of clinker being roughly six inches in diameter. The floor of this bed was concreted, with a gutter moulded in the concrete on the outer sides of the bed for the collection and discharge of the effluent, which eventually passed into a shallow pond.

"The clinker blocks were retained in position by four brick pillars built into the concrete floor at the four angles of the heap. The dimensions of this filter were:—Height, 3 ft. 9 in.; length, 9 ft. 6 in.; width, 7 ft. 6 in.

"The special feature of this filter is the 'distributor' or 'sprinkler,' by which the comminution of the sewage or

COMPARISON OF PURIFICATION—*continued.*

septic tank effluent is brought about. This consists of a number of narrow gutters arranged at right angles to the supply channel, and resting upon its margin and upon a suitable support at its distant end. The distributor is so connected with the supply channel that the liquid, on flowing over the margins of the latter, passes into the gutters of the distributors. Along the lowest part of the under surface of each gutter is placed a series of vertical points.

"The sewage or tank effluent entering the gutters by way of the supply channel flows over their margins, and on reaching the under surface falls from each of the vertical points (of which there are 360 to each square yard of filter), in a series of fine drops, on to the clinker heap below.

"It is claimed by the inventor that a filter constructed on these lines, and six feet in depth, will automatically and continuously purify upwards of 1,000 gallons of average tank effluent per day for an unlimited time; the oxidation being sufficiently thorough to render subsequent putrefactive changes impossible.

"But in my experiments the rate of flow was only 400 gallons per square yard of filter per day.

"In all, nine complete series of analyses were made of the screened and settled sewage, and of the resulting effluents from the septic tank, the upper and lower series of contact beds, and from the Stoddart filter." [*Professor Letts' Belfast Report*, pp. 18, 19, 20.]

According to these analyses, not only were the Stoddart bed effluents in every instance greatly inferior to those from double contact in respect of free and albuminoid ammonia, oxygen absorbed in four hours, and in their yield of nitrates, but as compared even with the first contact effluents, they show a decided inferiority in free and albuminoid ammonia, and a very slight superiority as regards oxygen absorbed. The first contact effluents, however, contained no nitrates. Although the comparison turns so strongly in favour of the contact beds, the efficiency of the latter is by no means high, the purification effected by the two contacts being less than that given by Mr. Harrison as the average for six months for a single contact at Leeds.

Dr. Letts sums up this section of this report as follows:—

"The results as regards the Stoddart filter have been

COMPARISON OF PURIFICATION—*continued.*

most disappointing, and contrast very unfavourably with those obtained by treating the same effluent on the contact beds. Not only is the diminution in the amount of the impurities much lower, but so also is the production of nitrates. In justice to the inventor of the filter, however, I give below not only the average of the results obtained by myself by his filter, compared with those obtained with double contact as regards the Belfast sewage, but also the results of his own experiments with a similar filter at Horfield, Bristol, on a different sewage:—

Results obtained at Belfast by a Septic Tank in conjunction with—	Average Percentage Purification in—			Average Nitric Nitrogen produced (parts per 100,000).
	Free Ammonia.	Albuminoid Ammonia.	Oxygen Absorbed.	
Stoddart Filter	8	28	37	0·12
Upper Contact Bed ..	22	34	36	—
Lower ,, ..	87	73	78	0·56
Results obtained at Horfield, Bristol, by the Stoddart Filter..	82	72	93	1 50

"Every attention was given in Belfast to the Stoddart filter, both as regards construction and working, as I was most anxious to investigate the effects of a really efficient 'nitrifying' filter, and also one of the 'continuous' type, in both of which respects I had heard the Stoddart filter well spoken of. Undoubtedly it suffers from a structural defect, namely, the difficulty in maintaining the 'distributor' in an exactly horizontal position for any length of time, as sudden gusts of wind upset the adjustments. It is, however, difficult to account for the failure of the filter in view of Stoddart's own results given in evidence before the Royal Commission on Sewage Disposal, in which an exceptionally strong sewage was dealt with. These results I have calculated into similar units, and, as already mentioned, have placed them in the above table." [*Ib.*, p. 30.]

It will be observed that the depth of the Stoddart filter was less than that mentioned by the inventor in his evidence, being

3 ft. 9 in. as against 6 feet, but in one of his pamphlets 2 feet is mentioned as "quite a practical depth for the bed where no more can be obtained."

The Stoddart filter was worked much harder per unit of capacity than the contact beds, but one of the claims made on behalf of the former is that it will do five times the work of the latter. There is no need to labour the comparison which Dr. Letts has made, or to infer that the Stoddart filter is not capable of doing good work; but in the presence of such results as these, and others which have been obtained elsewhere, it seems permissible to doubt whether the contact system is after all so much inferior in efficiency as some of its critics would have us believe.

Relation of Filter Capacity to Volume dealt with.

While the foregoing evidence is useful in showing the amount of purification effected under given conditions by the methods under consideration and the general character of the effluents yielded thereby, the results quoted cannot be used as an absolute basis for comparing their respective efficiencies unless due regard is paid to all the circumstances of each case. A moment's consideration will show that filters on either system can be made to effect any desired amount of purification, the only limit being that imposed in the one case by the number of contacts, and in the other by the depth of the filter.

For the purpose, therefore, of a fair comparison from a scientific point of view, we should take the amount of impurity removed by a given bulk of filter, or conversely the filter volume required to effect the desired amount of purification in a given quantity of the liquid to be treated.

The quantity of work done by a filter is usually expressed as so many gallons per square yard or per acre; but inasmuch as the volume which can be dealt with by a filter is governed rather by its cubic contents than by its area, it would be much more convenient for purposes of comparison to express the duty of a bed in terms of the former. It has been proposed to speak of the volume dealt with per unit of area of a given depth, but there is no good reason for assuming a depth which may or may not agree with the actual depth of the filters under consideration, and which, if it does not do so, may cause confusion. A simpler plan would seem to be to disregard arbitrary units, whether of area or cubic measurement, and express the flow as the numerator

of a fraction of which the volume of the filter is the denominator. Thus a contact bed having a water capacity of one-third, and filled three times per day, deals with one "measure." With a water capacity of 25 per cent., three fillings represent 0·75 "measures," and so on, a single ratio taking the place of the two or three quantities now generally used to convey the same information. For present purposes, however, more will be gained from a perusal of the evidence given as to the duty of various filters than from a bald table showing merely the quantities dealt with.

Quantity dealt with by Contact Beds.

The quantity dealt with at Exeter "would vary from 800,000 gallons per acre per day; it would vary from 170 gallons per square yard to about 200 gallons per square yard." [D. Cameron, 2033.] (The filters are five feet deep.)

"Do you consider that rate is a safe working rate—170 gallons per square yard per diem?—Anything up to 1,000,000 gallons; but I have worked at the rate of over 1,800,000 gallons per acre per day. [2036.]

"In storms?—In storms." [2037.]

"The quantity of sewage which can be treated on these beds was ascertained in the first instance at Barking Creek, where the one-acre fine bed treated chemical effluent at the rate of one million gallons of sewage per day, the bed being 3 feet deep. At Sutton, the coarse bed, having originally a similar depth, treated screened sewage without chemical treatment at the same rate, but prolonged experience points to a working rate, including all rest periods, of three-quarters of a million gallons per acre per day. This was with strong domestic sewage collected on the separate system. A larger quantity of weak sewage could be treated on the same beds. At Leeds, where the sewage contains quantities of manufacturing refuse, including solutions of iron salts, which absorb large quantities of oxygen, the same rate was maintained from January to June on a 4½-feet bed, viz., 770,000 gallons per acre, against 773,000 gallons at Sutton on a 3 ft. 6 in. bed." [Dibdin, 2170.]

Sir Henry Roscoe gives a table showing the volume of precipitated effluent per unit of area dealt with by the small experimental filters at Manchester, which ranged from 171 gallons

QUANTITY DEALT WITH BY CONTACT BEDS—*continued.*

per square yard per day in the first three months of 1896 down to 152 and 142 gallons in the March of the following year. The equivalent figures per acre per day are 827,640, 735,680, and 687,280 gallons respectively. Sir Henry was subsequently examined with respect to this table.

> "When you say that sewage can be treated at a maximum rate of 800,000 gallons per acre of filter, that would apply to the filter when first started. You are not making any allowanco there for reduction of capacity?—I have shown that so far no allowance is necessary. [3737.]
>
> "It may be reduced, as you have already shown on p. 308?—No allowance is necessary, because the filters are working now just as well as they did to begin with. Mr. Scudder reminds me that when the capacity began to diminish, and when we only put on the quantity of sewage which we put on to begin with, then, of course, the quantity of effluent diminished, and we were only able to get in the one case, instead of 800,000 we only got 735,680, and in the case of the coke filter only 687,280, so that there was a diminution, of course, when the capacity of the tanks had diminished by from 12 to 20 per cent.; there was a diminution in the volume of effluent filtered. [3738.]
>
> "Then you show again an increase by increasing the number of fillings?—That is so. The fact was that during the time we were working the filters had only three fillings per day in the twenty-four hours; they now find that they can put on four fillings. [3739.]
>
> "May that be taken as a permanent addition?—So it appears; they have gone on that way for some time." [3740.]

The work done by the Sutton filters was mentioned by Mr. Dibdin as follows:—

> "I may point out that, as an actual fact, the average per acre per day treated on all the beds is equal to 721,059 gallons. I am speaking of the coarse beds. The fine beds will do more." [3805.]
>
> "They will not stand three fillings per day continuously. In calculating on all new work, I take it as two fillings per day, and then I like to have a good margin upon that, because there is no doubt that the carbonaceous matters in sewage

QUANTITY DEALT WITH BY CONTACT BEDS—*continued.*

do take a longer time to go than the purely nitrogenous; and it is necessary, as you would in putting up a steam engine of certain horse-power, to provide a certain margin, and I think we may safely take a leaf out of the engineer's book in this matter." [3893.]

Mr. Latham, after describing the results obtained at Manchester, went on to say:—

"With bacteria beds three feet deep, there can be littlo doubt that the sewage of 10,000 people per acre ean be perfectly purified." [4505.]

Referring to this answer, General Carey observed:—

"That would come to about 300,000 gallons per acre?—Yes. The volume of sewage is much greater per head than 30 gallons. The Manchester flow of sewage varied last year from 38 gallons per head per day to 69⅓ gallons per head per day taken over an averago of one week. [4686.]

"Or say 60 gallons per square yard?—Yes. [4687.]

"Do you know that a much higher rate is elaimed for the Sutton system of filters?—Well, that is as much as I consider, after most careful consideration. [4688.]

"You consider that a maximum rate?—I consider that a maximum rate." [4689.]

"(Mr. Killick): Do you know the rate at which the water is passed over at the top" (at Kingston)?—"The actual per square yard? [Sillar, 5181.]

"Per day?—Yes; per twenty-four hours about 310 gallons per square yard." [5182.] (The filter is three feet deep.)

"Then, as the result of your experiments" (at Manchester), "you probably have reached a conclusion how much burden could be thrown upon primary and secondary beds; will you give us your opinion upon that?—I have como to the conclusion that you can work your primary beds at an average speed of three-quarters of a million gallons per acre per day if you give them Sunday's rest, and one week's rest iu the month. [Fowler, 5602.]

"When you say three-quarters of a million gallons per acre per day, do you mean tho coarse bed only, or are you including double filtration?—I am speaking of the first bed only. That is to say, I calculate my contents of the bed at one-quarter of a million; at three fillings, that amounts to three-quarters of a million. [5603.]

QUANTITY DEALT WITH BY CONTACT BEDS—*continued.*

"For that bed only?—For that bed only. [5604.]

"When one speaks of three-quarters of a million for one secondary bed following a primary bed, the volume per acre will be half that?—Half that. If you had one bed for one secondary, certainly, yes. [5605.]

"If you have one secondary bed following two primary beds, what would be the volume per acre which you would find practical to be dealt with?—Well, that would be half-a-million gallons." [5606.]

"Now as to the area of contact beds that would be required for Leeds sewage. Have you formed an opinion?—Well, when our double contact beds were in good working condition and dealing with about 50,000 gallons per filling, and three fillings per day—that is 150,000 gallons per twenty-four hours—this would represent 1,200,000 gallons per day per acre, since the area of each bed was about $\frac{1}{8}$ acre. There were, however, two beds, a rough and a fine, so that only 600,000 gallons per acre of beds could be dealt with. Allowing for necessary periods of rest, half-a-million gallons per acre might be reckoned; and for 16,000,000 gallons, the Leeds dry-weather flow, 32 acres would be required. But the beds would not last long at this rate, and the volume dealt with would rapidly diminish. If, as a basis of calculation, the reduced rate of working of the summer of 1899, viz., one filling per day, is taken, there would be required 96 acres of double beds, an area which, I fear, would be prohibitively costly. Apart from cost, an area which would permit of one filling a day of the dry-weather flow would be convenient, because the fillings could be increased during rain and for short periods to three or more per day. But I have come to the conclusion that for Leeds sewage the system of intermittent or contact filtration is impracticable, although good filtrates are certainly obtained." [Harding, 7068.]

"At Barking, a portion of the sewage, equal to one million gallons per acre, is dealt with on their 6-foot bed; but I believe it to be true that when you come to deal with the whole of the flow, owing to the small quantity which comes in the night and the big rush in the day, that you cannot get sewage through them at that rate." [Strachan, 7726.]

Quantity dealt with by Contact Beds—*continued.*

Evidence (by Mr. Fowler) has already been quoted showing that no ill effect is traceable to diurnal variations in the length of the cycle (p. 165). It has also been shown (p. 165) how these variations were eliminated at Barrhead.

"Can you suggest to us what rate is likely to be attained by contact beds?—Well, in practice, Sir, what I do is to provide about 3 acres per million." [7727.]

"I think, I have always in my own mind worked it out, that you can effectively or efficiently purify septic effluent in Manchester at the rate of about half-a-million gallons per acre with careful working. [Fowler, 8560.]

"On single beds—not double contact—single contact beds? —Single contact; a certain amount of double contact, possibly, in the future. [8561.]

"Then, is your half-million gallons based on single contact, because I take it that with double contact that would reduce it to a quarter of a million?—Oh, no; I take it rather in this way, that if you are beginning—for instance, if your beds are not matured, and if their capacity is not decreased, you can get much more than half-a-million through, you can get up to a million with a high capacity, but it will not be so effectively purified, and then you will have to have recourse to double contact. But I am speaking of adequate purification, either by single or double contact as the case may be, because we find that with the decrease of capacity you get, as I said before, increase of efficiency, so it is difficult to say absolutely, if you follow me, whether it is half-a-million single contact or half-a-million double contact. I should prefer to put it half-a-million gallons effectively purified at that rate, either by a single or double as the case may be." [8562.]

"*Initial period of working.* Care will be taken at the commencement of working to put no more work on the bed than it is capable of performing, as it is difficult to thoroughly recover a bed if it has once been overworked. For example, two fillings a day should not be exceeded until good nitrification has been obtained." [*Interim Report*, vol. II., p. 467.]

" Shall I be right in taking it that in normal conditions" (at Burnley) "you pass two fillings at tho rate of 300,000

gallons per twenty-four hours?—Practically that. [Pickles, 15329.]

"And that is increased to 450,000, or even more in times of dilution?—Yes. [15330.]

"And you think, from your experience, that you can continuously deal with 300,000 gallons per acre on these beds?—Yes; we think there will be no difficulty in that." [15331.]

The coke-beds at Crossness were filled four times per day, but the water capacity gradually fell off. Referring to the loss of capacity, Dr. Clowes remarks:—

"This would no doubt be largely avoided by more perfect previous sedimentation of the sewage, and by more energetic septic action." [*L. C. C. Fourth Report*, p. 21. See also p. 318.]

Quantity dealt with by Streaming Filters.

"We have not been able to arrive at any very definite conclusions as to the amount of sewage that these filters will purify from one year's end to the other, but I am not inclined to put it as high as, perhaps, we were led to suppose at one time we should be able to go. I think myself that the limit will be found somewhere at about 500,000 gallons per acre for that class of filter." [Crimp, 1593.]

"(Mr. Killick): Is that clarified sewage?—That is clarified sewage after it has been treated with chemicals. [1596.]

"(Major-General Carey): About 100 gallons per square yard?—About 100 gallons per square yard is a very good figure." [1597.]

"These Friern-Barnet filters are about 1·44 acres in extent, and have been dealing with the sewage of between 6,000 and 7,000 persons per acre." [Latham, 4505.]

"Our rate of filtration" (at Chorley) "is about 450 gallons per square yard per twenty-four hours. The filters are washed weekly. They filter more rapidly after being freshly washed, and slower, of course, towards the expiration of their time." [Hibbert, 7761.]

Quantity dealt with by Trickling Filters.

"As a general rule it may be taken that each square yard of filtering area will satisfactorily purify 200 gallons of sewage daily, or one acre of filter suffice for one million of

Quantity dealt with by Trickling Filters—*continued.*

gallons a day, and the depth of the filter may vary according to the nature of the sewage to be treated on it and the amount of purity required in the effluent. Where the effluent is to be discharged into the sea or brackish water, as at London, a depth of filter of 5 feet would in most cases suffice; a filter 8 feet deep will give an effluent pure enough to meet the requirements of any river authority and to go into any stream no matter how small; but if the effluent is to go into a small stream, the water of which is liable to be used for dietetic purposes, it would be well to make the filter 10 feet deep or more. For the treatment of the waste water alone of certain trades a filter 12 or 15 feet deep may be necessary." [Ducat, 2187.]

"The filter was designed to take 24 gallons per square foot per twenty-four hours, and that gives a little over 1,000,000 gallons per acre per day, but it is going to do considerably greater duty than that." [Scott Moncrieff, 3395.]

"I think that except with an exceptionally good effluent, such as that at Buxton containing nitrites, that the rate of filtration should be not exceeding 250 gallons to the squaro yard in the period of twelve hours, the filter then to have a rest of twelve hours." [Barwise, 4033.]

"At Accrington we filter 600 gallons of settled sewage to the square yard, and that is when sewage is about 0·4 albuminoid ammonia per 100,000. We have just had some rather dry weather; we have had a whole month not only of cold but dry weather, and our tank effluent reached 1·1 of albuminoid ammonia. On account of the albuminoid ammonia in the final effluent getting up, we reduced tho flow to about 400 gallons." [Whittaker, 4825.]

"We have put it on to the extent that the distribution has been greater than the areas of flow in the filter, and that is reached at about 1,200 gallons to the square yard; that is, when we put on 1,200 gallons to the square yard the films are too thick, and tho body of the filter seems to become waterlogged, and at the top you have a pool for the moment. [4832.]

"But short of that you may increase the quantity so as materially to influence the charactor of the effluent?—Yes; here with a tank effluent, 1·1 for instance, had we to have

QUANTITY DEALT WITH BY TRICKLING FILTERS—*continued.*

put on 1,000 gallons to the square yard we should then have had a very muddy and cloudy effluent, because it was so strong that it would have been utterly impossible for the filter to have dealt with it." [4833.]

"The efficiency of the filter continues as you diminish the quantity." [4835.]

"With about ·5 of albuminoid ammonia we say that 600 gallons is the limit to which you ought to go. If you want a better effluent, come down from 600 to, say, 400. But if you increase it above the 600 you then begin to get an unsatisfactory effluent. That is, we say, satisfactory, because we work at ·1 per 100,000." [4836.]

"The speed of filtration I recommend you to adopt is at the rate of three square yards for every 1,000 gallons of sewage per 24 hours." [Prescott, 6986.]

"The filtration through a polarite sprinkler oxidising bacterial bed may safely be taken at 500 gallons per square yard per 24 hours, or 2½ million gallons per acre." [Candy, 7033.]

"The bed was started on March 9th, 1899, at the rate suggested by Mr. Whittaker, of 600 gallons per square yard —that is at the rate of 3 million gallons per acre per 24 hours. [Harding, 7355.]

"We soon found we could not long continue to work at that rate. . . . . The flow was therefore reduced to 200 gallons, or one-third, and this gave improved filtrates, but the pooling continued, and it became necessary to rest the bed for a few days." [7356.]

"In these conditions, and working at the rate of 250 gallons per square yard, the experiment went on for three months before the pooling of the surface arose, and it became necessary to fork over." [7358.]

"This experiment was a very useful and suggestive one, but showed that with the effluent from the Leeds septic tanks, which contained an average of 13 grains per gallon of suspended solids, the bed had been constructed of material too fine, and we therefore resolved to construct another bed of much coarser material, and make further trial of the system." [7361.]

"The rate of filtration was 1,000,000 gallons per acre (*i.e.*, 200 gallons per square yard) per 24 hours working

QUANTITY DEALT WITH BY TRICKLING FILTERS—*continued.*

night and day. The bed was started on September 2nd, 1899. The first filtrates obtained were exceedingly clear but putrescent, showing that, though solids in suspension were being kept back, bacterial action was not yet developed. This continued until September 19th, when the filtrate became turbid from suspended solids coming out; but, nevertheless, nitrates were present, and the filtrates were non-putrescent in character. Since then the filtrates have remained turbid but non-putrescent." [7362.]

The filters referred to in the last five extracts dealt with tank effluent. Colonel Harding went on to speak of the "Leeds filter," in which crude sewage was treated.

"The Leeds bed was started on December 7th, 1900, at a rate of 200 gallons per square yard per 24 hours, which on January 21st, 1902, was increased to 400 gallons per square yard." [7382.]

"The effect of the filtration of 400 gallons had been to somewhat reduce the excellence of the results, not very materially, except that it reduced the proportion of nitrates." [7386.]

The following evidence was taken at Leeds, nineteen months later:—

"The filter beds of the Whittaker?—We are working them now, turning the effluent from them at the rate of 400 gallons per square yard, or 2,000,000 gallons per acre. [Harrison, 14978.]

"(Colonel Harding): That would be 400 gallons?—Four hundred gallons per square yard, and they last about seven weeks. [14979.]

"(Sir William Ramsay): Is there much difficulty in cleaning?—The solid matter dries very rapidly. It cracks up and separates very easily from the surface of the fine coke. [14980.]

"(Chairman): So that if you have a series of them you can use them conveniently one after another; if you have a large enough series, by the time you come back to your first one it can be readily cleaned?—Yes; in fact it can be removed easily at the end of a month after stopping the inflow of liquid on to the area." [14981.]

Quantity dealt with by Trickling Filters—*continued.*

Reference was made to the doublo contact beds, which were treating approximately half a million gallons per acre.

> "And in the case of the Leeds bed you are treating?—We are treating a million gallons per acre. [15071.]
>
> "(Chairman): Twice as much?—Twice as much for the area covered by the filter. [15072.]
>
> "(Colonel Harding): The filter is of greater depth?—In the case of the Leeds filter it is 12 feet deep." [15073.]

At the Salford works Mr. Corbett explained how storm water would be dealt with, and was asked—

> "And how do you know that you can use the filters continually without rapid choking?—We tried two experimental filters for a period of twelve months. The order was given to run them night and day continuously, at a flow of 1,000 gallons per square yard. They were served by a steam engine, and the man had to stop the filters for half an hour or an hour just to clean up and oil his engines; but barring that and incidental stoppages for a few days, we ran these filters for twenty-four hours for twelve months with excellent results all through." [Corbett, 15475.]
>
> "Whilst they are working they are run at the rate of 900 gallons per twenty-four hours. [15490.]
>
> "So that running only eight hours you average 300 gallons per square yard?—Yes, that is one-third." [15491.]

Mr. Stoddart gave the following evidence with regard to the quantity of tank effluent dealt with by filters in his system:—

> "Experimental filters at Horfield have been running continuously for many months; one in particular, one square yard in area, having been at work without interruption since October 6th, 1899. Here the effluent from a precipitation plant is treated, but owing to its very exceptional strength the quantity has to be reduced in dry weather to about 500 gallons per square yard daily.
>
> "A larger filter, 30 square yards in area, was erected in October, 1899, to deal with the effluent from a septic tank into which the sewage of Knowle, a suburb of Bristol, is drained. This filter has been running quite continuously since January 30th with uniform success, though occasionally nearly 10,000 gallons has passed through each square yard

QUANTITY DEALT WITH BY TRICKLING FILTERS—*continued.*

daily, and the average dry weather flow is about 1,300 gallons per yard." [Stoddart, *Interim Report*, vol. II., p. 291.]

"The average rate of flow through the" (Stoddart) "filter up to December 26th, 1900, was 240 gallons per square yard per day; this has since been increased to about 350 gallons per square yard, and the filtrate is of fair quality." [Fowler, *Interim Report*, vol. II., p. 467.]

Dr. Reid, in his Hanley Report, says:—

"A rate of flow of 200 gallons per yard per 24 hours was decided upon, because experience had shown in the case of other works that such a rate could not be exceeded without greatly reducing the degree of purification obtained. . . . .

"In future it might be well to test the power of the filters of dealing with an increased volume per 24 hours, and the distributors might be worked at different rates of travel, as it does not follow that a rate of 200 gallons per yard may not be exceeded with impunity in the case of filters worked under such perfect conditions as regards distribution, neither is it certain that the most effective inter-delivery period is seven minutes. . . . .

"The rate of travel of the distributors was so adjusted that each yard of filter received its quantum of sewage at seven minutes intervals—the time recommended by Mr. Scott Moncrieff as the outcome of his experience in the working of biological filters designed by him some years ago." [Hanley Report, pp. 5, 6. See also p. 318.]

OBSERVATIONS ON CONTACT BEDS.

If the criticisms which are launched against the contact system are valid, it follows, as a necessary consequence, that the system is capable of being so applied as to yield much better results than are now obtained from it. For, if the time during which the liquid is held in contact with the material is wasted, the shortening of this period would enable the filter to do more work; and if, as the result of this contact, the oxidising bacteria are "enfeebled, surfeited and asphyxiated," a substantial curtailment thereof should enable them to perform their functions so much more effectively as to bring about a marked improvement in the effluent.

Observations on Contact Beds—*continued.*

This reasoning finds some support in the results already attained. In the early days of bacterial treatment it was customary to devote a large part of the cycle, to the extent of one-half or more, to the operations of filling, resting full and discharging, leaving barely one-half of the time for resting and aeration. It has now come to be recognised that the period allowed for aeration may, with advantage, be extended at the expense of the others. The writer has for many years worked on this principle, as an instance of which he may mention that the apparatus which governs the filters of the experimental septic tank installation at Leeds is so designed that the filling, resting full, and discharging of a bed occupy only about one-sixth of the whole cycle, leaving no less than five-sixths of the time for the draining and aeration of the material. The purification effected by these filters during the six months ending September, 1902, is given by Mr. Harrison as 72 per cent. in albuminoid ammonia, and 87 per cent. in oxygen absorbed. (See p. 233.) The purifications by double and triple contact, on the basis adopted by the Manchester experts (see p. 166), would be 75 per cent. and 87·5 per cent. respectively; while at Leeds there is only a single contact. Other instances of high purification effected by single contact are given in Dr. Clowes' fourth report to the London County Council (quoted p. 234) and in the tables to a paper on sewage disposal read by the writer in 1901 at the Eastbourne Congress of the Royal Institute of Public Health. It is quite possible, in beds which are fully matured, to shorten the filling and contact periods still further, so that the most ardent advocate of prevention of cruelty to microbes may no longer have cause to complain of the suffocation of the latter.

The question will doubtless be asked, "Why fill the filter at all?" The answer is to be found in the evidence given before the Commissioners, and the complaints which one hears, whenever the subject comes up, as to the lack of a satisfactory system of distribution for trickling filters. [See pp. 188, 189; also 4925, 7457.]

However faulty the contact bed may be, considered from a theoretical point of view, it should never be forgotten that by its introduction Mr. Dibdin gave to the world an absolutely perfect system of distribution. It has yet to be shown that its defects, real or alleged, in other directions outweigh the great practical advantage which this confers. If, with bated breath,

one may make such a suggestion, the writer would venture to point out that the trickling filter itself is not wholly beyond suspicion of complicity in the cardinal sin of the contact bed. Dr. Reid, on page 8 of his Hanley report, refers to "a temporary waterlogging of the large-grained section of the circular filter," which, in this case, was corrected. Is it not possible that something akin to waterlogging takes place in certain parts of many trickling filters, especially those in which due care has not been taken with the grading of the material? In such a filter it is easy, as pointed out by Mr. Whittaker (p. 193), for the effluent to find for itself definite channels, and this state of things, once set up, would tend rather to perpetuate itself than otherwise. It may be said that the condition referred to is no worse than that which prevails throughout a contact bed; but this is hardly correct. In a contact bed, the waterlogging is of short duration; and after each recurrence thereof every crevice of the filter is aerated as freely as the capillarity of the material will permit. With a trickling filter, on the other hand, further supplies of effluent, loaded with oxygen-consuming compounds, may flow for hours down tho same channels, from which air is effectually excluded, thus setting up an unequal distribution of conditions through space not less mischievous than the cyclical changes which occur in a contact bed.

Suspended Matter in Filtered Effluents.

Another consideration which has to be taken into account in a comparison of the two modes of filtration was pointed out by Colonel Harding and several other witnesses:—

> "Doubtless you have already had it in evidenco that the effluent after treatment" (in the Whittaker filter) "contains solid matter in suspension. The amount of total solid matter in suspension varied from 2·9 to 5·3 grains per gallon. The permanganate 4-hours test varies from 0·98 to 1·30 grains per gallon. The albuminoid ammonia varies from 0·144 to 0·201 grains ammonia per gallon. The standards are exceeded. If, however, you remove the solids in suspension by sedimentation or filtration, and then analyse the liquid, you will find that it then complies with the standards. Tho albuminoid ammonia drops down to considerably below 0·1. I have a table here." [Scudder, 5965.]
>
> "For that reason it is necessary, in practice, to deal with the suspended matter from the Whittaker and Bryant

SUSPENDED MATTER IN FILTERED EFFLUENTS—*continued.*

filter before allowing the effluent to escape into the river." [5966.]

Mr. Prescott, in his Report to the Reigate Sewage Farm Committee, refers to the subject as follows:—

"Experience has proved that a little solid matter is always produced from bacteria beds, and it is of the utmost importance that this 'burnt-out ash,' as it is termed, should not be retained in the bed, but should be discharged with the effluent, from which it can be easily removed by settlement. This condition the sprinkler beds comply with." [6986.]

Mr. Candy mentions that in a fine bed formed with $\frac{3}{4}$-inch material—

"Even fairly large suspended matter can freely pass through and become oxidised." [7026.]

Colonel Harding refers as follows to the first appearance of suspended matter in the effluent from the No. 1 Whittaker bed at Leeds:—

"The filtrate continued to be clear to July 30th, but from the latter date large quantities of brown suspended matters came out from the bed, causing the values obtained from the Alb. NH_3 and oxygen absorbed tests to rise considerably. The free NH_3, however, remained very low (about ·2), whilst the N as nitrates remained over ·7 grains per gallon, showing that the aeration of the bed was not being interfered with. The coming through of these solids in suspension in the filtrate was at first very disappointing, and was looked upon as condemning the system. Further experience, however, has shown that a large part of these solids are irreducible, and, therefore, if they do not come out, but stay behind in the filter, they must necessarily choke it up. They were soon found to be non-putrescible, and to be readily settled." [7358.]

The suspended matter in the effluent from the fine Whittaker bed (No. 1) during the fourteen months ending May 8th, 1900, averaged 8 parts per 100.000 [Harding, 7360], and that from the No. 2 Whittaker bed (in which coarser material was used) 11 parts. For the six months ending September, 1902, the amount is given as 6·9 parts. [Harrison, 14912.]

SUSPENDED MATTER IN FILTERED EFFLUENTS—*continued.*

Mr. Fowler, in his Manchester lecture, says with reference to this:—

"The matters in suspension in an effluent from bacterial filters are of great importance. It may frequently happen, especially in the case of continuous filters, that considerable quantities of suspended matters pass away in the effluent. It may also be that the effluent, when incubated along with these suspended matters, is not putrefactive. It must not, however, always be concluded that the suspended matter is harmless, as, if allowed to settle, the clear filtrate poured off, and the suspended matter separately incubated with distilled water, then it will often be found to be putrefactive. The character of suspended matter which separates from filtrates under various conditions requires careful study. Perfectly clear land filtrates may, on standing, give ferruginous deposits, partly due to oxidation of iron present originally as organic ferrous salts, and partly due to the presence of bacteria, which collect and separate iron from solution, *e.g.*, crenothrix."

"The same may take place in the effluent from contact beds, especially where the sewage contains iron pickling refuse in solution. In the case of open, continuous filters, actual suspended matter from the septic tank may find its way in an unoxidised condition through the filters. In all these cases the organic and volatile matter may also be in a large degree due to growths of organisms of one kind and another, sometimes, it may be, of a fairly high order, *e.g.*, infusoria, &c.

"In general, it may be said that the more perfect the action of the bed the more harmless or more thoroughly oxidised will the suspended matter be, until finally it may be rightly described as organic residuum or débris. It must, however, if present in more than traces—3 grains per gallon (4·3 parts per 100,000) have been suggested as a limit—be removed from the effluent by straining or settlement.

"The experience of Leeds would show that an effluent containing large quantities of suspended matter can be strained through 6 inches of sand at the rate of two million gallons to the acre, or about six hours' settlement is neces-

> sary. Much less than this is generally given, but as a rule it is not adequate." [Manchester Lecture, p. 17.]

(See also 4885, 5806, 5969, 7057, 7063, 7388, 7432, 14965.)

The Leeds filter sends out an exceptional amount of suspended matter, averaging for six months no less than 27 parts per 100,000. [Harrison, 15031.] This is, of course, far more than can be admitted to any stream, so the "effluent from the Leeds filter is subjected to an alternativo treatment; one is settlement and the other is filtration." [15035.] "The settlement is a 12-hour flow through an ordinary settling tank." [15036.] The filtration takes place through a 6-inch layer of very fine clinker, at the rate of 400 gallons per square yard per day. [15039-15041.]

In considering these facts, it should be borne in mind that the Leeds filter deals with crude sewage, thus saving preliminary treatment, the cost of which would probably amount to more than that of the subsequent straining or settlement. The necessity for settlement also arises, however, with most of the trickling beds which do not deal with crude sewage, and must therefore be taken into account in estimating their cost.

Cleansing and Renewal of Filtering Material.

On the other hand, it is claimed for the trickling filter that it is self-cleansing; whereas it is contended that the material in a contact bed will eventually require removal and washing.

> "When a continuous filter becomes so far choked that it is no longer efficient, can anything be done to clear it?—That is, of course, a very important point. We had noticed in this filter, and also in our earlier Whittaker bed, that if, for any purpose, the arms of the sprinkler were held from rotating, then, within a few minutes, the filtrate became very turbid, and with an excess of solid matter coming out. This was due to sending the whole volume, which during the rotation of the arms is distributed over the whole surface, through only a small part of it, and so increasing tenfold the flow through that part. This suggested that with a coarse bed like this No. 2, the bed could be washed out. Accordingly, a three-inch hose, with town's water, was turned on one square yard of the bed, and successively over the whole surface. The bulk of the accumulated solids came out in the first three minutes, during which the filtrate was exceedingly turbid; a test tube, with ten inches in it,

CLEANSING AND RENEWAL OF FILTERING MATERIAL—*continued.*

settling down three inches of sludge. After the first few minutes the volume of solids coming through rapidly diminished. With these washed-out solids came out an immense number of cyclops, larvæ, &c. The sludge was found only slightly putrescent, although it would necessarily contain organic matter in process of transition. No doubt, if the experiment had been made after a rest of one or two days, the sludge would have been as little putrescent as that which comes out in the normal flow. The filtrates obtained immediately after the washing out were not good, and it took about a fortnight to bring them to the old standard, and indeed they then so far improved that the nitrates rose to 1·31 grains per gallon. No doubt in this suggestive experiment the washing out had been too thorough, and some bacterial life had been cleared out with the accumulations. [Harding, 7363.]

"Do you suggest, then, that practically such beds may be washed out by turning a hose upon the surface?—Oh, no; that would, of course, be too costly. The washing out of accumulations would take place by increasing the flow, say, from 200 gallons, if that is the normal rate, to 400, 600 or 1,200 gallons per square yard. Such increased flow would arise automatically with rainfall and dilution of the sewage, so that after storms the filters would recover their full efficiency. This is an important feature." [7364.]

"I think that in trickling filtration over coarse material, where suspended solids come out always in the filtrate, and accumulations are at times washed out, it will probably be necessary to have a settling tank at the end of the process, unless the filtrate can be passed over land. It is well to note that these washed-out solids are at Leeds non-putrescent. I understand that they are putrescible in the Accrington filtrate, the difference being probably due to the large quantity of iron in Leeds sewage." [7366-7.]

"(Sir William Ramsay): Have you to wash out the Whittaker often?—The Whittaker bed has now been working three years and over, and we have washed it out twice during that period. This year we have not touched it at all. It has been helped this year by the very heavy washes of solids coming from it towards the end of spring." [Harrison, 14987. See also 7464, 15088-9.]

CLEANSING AND RENEWAL OF FILTERING MATERIAL—*continued.*

If the washing of trickling filters in the manner described were likely to be of frequent occurrence, it would seem to be necessary to lay down a second plant at a lower level for the purification of the washing water; but if it does not require to be done oftener than once a year, this might doubtless be dispensed with.

Referring to the possibility that the material in contact beds may have to be washed, Mr. Fowler says:—

> "In addition to the work on the surface of the beds above mentioned, it may be necessary at very infrequent intervals to wash a portion at least of the main bulk of the material. Experiment has shown that it will not be economical to wash the surface layer, but the larger clinkers below should be capable of being rapidly and cheaply washed in a specially devised machine. The slurry may be allowed to run off along specially constructed channels to the surface of one of the storm beds, where it can be allowed to dry, and afterwards spaded off. It has been found that such slurry, or washed-out material, is perfectly inoffensive and dries down to a substance having the character of garden mould." [*Interim Report*, vol. II., p. 468.]

In this connection it is interesting to note Mr. Strachan's evidence with regard to the necessity which is sometimes assumed for renewing the material in contact beds from time to time:—

> "You think that an expenditure of £2,000 an acre would not be prohibitive provided it did not arise too frequently?—Yes; might I just mention the case on which I base that opinion, because I have the facts at Exeter? They have been working for three and a half years on 31,380 gallons a day. During that time those contact beds have dealt with 40,000,000 gallons of dry-weather sewage, excluding rain. Now they have 670 cubic yards of filtering material in those beds. Supposing they dealt with it by what I suppose would be the alternative, namely, a chemical process. I do not know of any other alternative, and that is what I base my estimate on. Then the chemicals would have cost them £60, dealing with sludge would have cost them £130, and I think they would have required one man extra to look after the chemical works as compared with what they would require to look after the septic tank and contact beds. In three

and a-half years it would have cost Exeter £400 to deal with the 31,380 gallons of sewage. Now assume—it is not a fact, but assume—that those beds are done for. Well, Exeter could afford to pay 10s. a cubic yard to renew them at the end of those years, and be £65 in pocket." [Strachan, 7721.]

As has already been mentioned, it seems feasible by taking proper precautions to postpone almost indefinitely the necessity for washing or renewing the material. (See pp. 171 *et seq.*)

Growth on Filter Surface.

Some of the witnesses drew attention to a peculiar difficulty which is occasionally met with in the working of trickling filters.

"I am disposed to think that 200 gallons per square yard is a sufficient rate for a normal flow over such a bed, and I should like to add this: that working at 400 gallons we are beginning to be troubled with the excess of growth of the pilobolus on the surface of the bed. This is a growth which develops most extraordinarily on the surface of the beds. We had at one time a great deal of trouble with it on the Whittaker bed, when we worked at a large rate per square yard. It exists always, of course, on the Leeds bed, but, working at 200 gallons, it did not choke the surface; working at 400 gallons, we find that the growth of the pilobolus is excessive, and is tending to pool the sewage on the surface of the bed. I have formed the opinion, therefore, that it would not be wise to work continuously at the 400 gallons rate, but that it would be quite practicable to work continuously at the 200 gallons rate, and that it would be practicable to work for a short time at the 400 gallons rate, and I should think at a much higher rate with dilute sewages." [Harding, 7386.]

"(Chairman): There is a growth on the surface?—On the top of the filter there is. [Harrison, 14990.]

"Would that have to be removed?—The growth grows very rapidly towards the beginning of spring. The temperature of the sewage seems then to be at the best point, and the sewage in the best condition for its growth, and if we once clear that period we are all right for the rest of the year. We have at that time to keep continuously forking the surface of the filter." [14991.]

This trouble does not seem to have been experienced at the Accrington works:—

> "You have not been inconvenienced by the presence of any growth on the surface?—None whatever." [Whittaker, 5790.]

Mr. Candy contends that it may be avoided by feeding the beds intermittently, as is done in his system. [7022.]

The growth of pilobolus upon the surface of Stoddart filters has already been referred to (p. 188).

Attention required.

Apart from this special difficulty, the evidence seems to show that trickling filters need rather more looking after than contact beds. The amount of attention required by both has already been referred to, and it is only necessary here to add that Dr. Bostock Hill, in his paper read at Birmingham in September, 1903, in which he expressed his preference, "from a scientific point of view," for the continuous or streaming filter, took care to point out that there were "some difficulties attending its use," and that "it requires more care and observation than the contact bed." [*Journal San. Inst.*, vol. XXIV., p. 838.]

The modes of distribution which are generally used with trickling filters will probably be found to render them more susceptible to frost than contact beds.

Relative Cost of Modes of Filtration.

The information obtainable from the evidence as to the cost of works on various systems is extremely scanty, and altogether inadequate for purposes of comparison. This was inevitable, and in view of the inveterate tendency of a large section of the sanitary public to indulge in sweeping generalities on the slightest provocation, it is probably just as well that the Commissioners have refrained from giving them a lead. It may be noted here that much of the popularity which is enjoyed by the trickling system is undoubtedly due to the expectation, which has been industriously fostered, that it would enable many times as much work to be got out of a given area of filter than was possible by means of contact.

Relative Cost of Modes of Filtration—*continued.*

Experience has shown that these expectations were founded chiefly on faith and hope, the excess of which virtues may perhaps be set against the lack of charity evinced by their possessors when the contact system has been in question. The practice of the Local Government Board in calling for the same filter capacity, whether for trickling or contact, constitutes a wholesome corrective for the extravagant views referred to.

It has already been pointed out that, for the purpose of a comparison which shall be just from a scientific point of view, regard must be had not so much to the area of filters required to deal with a given volume of sewage as to the quantity of filtering material which must be provided.

An engineer called in to advise a local authority has to approach the matter from yet another standpoint, for, so far as his clients are concerned, the area, or even the capacity of the filters which he lays down, is far less important than the cost of the works, taken as a whole, and including interest on outlay and annual working expenses; and it by no means follows that the system which requires the smallest amount of filtering material will be the most economical either at the outset or in the long run. Taking the filtering material first: if only large pieces are to be used, as in some of the trickling filters, for every cubic yard which is fit for use, as much or more may have to be rejected, making the finished material much more expensive than that for the contact beds at Manchester, for instance, where the cinders were used almost as they came to the works. Whether the material is to be large or small, or is required for trickling or contact beds, the necessity for a uniform gauge will add appreciably to the cost.

The mode of construction of the filter has also to be considered. The omission of solid side-walls is claimed as an economy effected by some of the trickling filters, but, taking it all in all, it is doubtful whether the saving under this head is so great as would at first appear. The cost of the distributor, too, must be taken into account; though, as pointed out by Mr. Stoddart, it is true economy to spend money wisely in this direction. The question of distribution was referred to at the Provincial Sessional Meeting of the Sanitary Institute at Birmingham by Dr. Rideal, who said:—

"It was certainly worth while to pay much attention to the method of distribution, and put in a costly if an efficient

Relative Cost of Modes of Filtration—*continued.*

> distributor, if they could get an increase of even a few gallons per square yard per day in the flow through the bed." [*Journal San. Inst.*, vol. XXIV., p. 844.]

The real cost of a filter does not always end with the money which is expended on the construction of the filter itself, for where, as frequently happens, fall is scanty, and it is only by the severest economy in this respect in designing the sewers that so much as a couple of feet can be spared for the purification works, the extreme flexibility of the contact system as regards the fall which can be made to suffice has an important bearing on the cost of the works.

> "Is it not one of the most important points? Because in many cases the difficulty in disposing of sewage is want of fall, therefore a shallow bed might be used, and a deeper one could not without pumping.—It is a most important matter; no doubt land treatment may be used in such a manner as to be the same as using very shallow beds covering a large area. [Harding, 7134.]
>
> "Quite so?—Where your area is valuable the same results could be obtained by using a greater depth of material by artificial filtration. It is largely a question of local circumstances and engineering. I might just on that point remind Professor Ramsay that Mr. Fowler, of Manchester, has tried a shallow bed fifteen inches deep with good results." [7135.]

This is only what might have been expected from a consideration of the principles on which the contact bed is based, and were it not for the cost involved in spreading filters over a large area, there is no reason why still shallower beds should not be used.

In this connection regard must be had not merely to the depth of the bed itself, but also to the fall required by the mode of distribution. The apparatus which controls the filling and discharge of contact beds can generally be so arranged as to absorb no fall beyond the actual depth of the bed. For a Stoddart distributor an additional 2 or 3 inches will suffice, but with a rotary sprinkler more will be required. Mr. Candy mentions the necessary head on the jets as 3 or 4 inches, to which, for the sprinkler in question, must be added the depth of ponding and the clearance from the jets to the filter surface.

The total fall required for a trickling filter is estimated by many of its exponents at from 5 to 6 feet as a minimum, as against, say, 1 foot for contact beds. If, to get the additional fall required by the former it becomes necessary either to lay down pumping plant or to shift the works to a more distant site, this will be an important factor in the cost of the scheme as a whole.

Another consideration which bears on the choice of a site was pointed out by Dr. Bostock Hill at the Birmingham meeting already referred to, where he said:—

> "that it was impossible to adopt a method of distribution which would spray a large quantity of septic sewage in the open air in the neighbourhood of towns without causing a nuisance." [*Journal San. Inst.*, vol. XXIV., p. 844.]

CHAPTER XVI.

FILTERS VERSUS LAND.

Throughout their investigations the Commissioners have kept steadily before them the idea of land as the natural and proper means for the purification of sewage; and the various artificial processes which they have considered have had to justify their existence by comparison therewith.

Filters inferior to Land.

Several witnesses, whose position and experience invest their utterances with great weight, expressed decided opinions as to the superiority of land treatment. Many answers of this kind were quoted in the opening chapter, and a few more may appropriately be cited here.

> "I quite agree that land filtration is far supcrior to the other. I should only sanction artificial filtration if suitable land cannot be obtained." [Tatton, 465.]
>
> "By artificial filtration—I mean biological filtration—you cannot produce an effluent so puro as you can by land treatment." [Scudder, 519.]
>
> "Land treatment, where it can be applied, is the best; but where the difficulty of obtaining sufficient land arises, recourse must be had to artificial filtration through porous material." [*Interim Report*, vol. II., p. 34.]
>
> "I think that the average of land filtration, as in the Riding, is better than the average of artificial filtration." [Dr. Wilson, 1014.]
>
> "You would adopt that mode of treatment in preference to artificial filtration?—I invariably recommend all the authorities I am advising—if I can find a suitable area of land I invariably recommend them to go to it in preference to any other system." [Crimp, 1763.]

"The best effluents I have submitted to me are after treatment by land." [Scudder, 5972.]

Mr. Mawbey adduced a concrete instance of the superiority of land treatment:—

"Shortly it is this, that the detritus tank, the first contact, and the application to one plot of old pasture is equal to the detritus tank and three contacts, and superior to the detritus tank and two contacts." [Mawbey, 8262.]

"I suppose there can be little doubt that if land can be obtained at a sufficiently low price it would be possible to purify the sewage at a smaller expense on the land than by means of artificial beds." [Dr. Frankland, 9950.]

(See also 259, 505, 515, 556.)

FILTERS AS GOOD AS LAND.

Other witnesses (and some of those above referred to, in other parts of their evidence) held that as good work could be done by artificial filters as by land.

"Do you consider that there is a fair hope that by artificial treatment you will be able to get an effluent as good as you can get by land treatment?—I do not think there is a shadow of doubt about that, and I would like to try to make an explanation in this way. You examine any ideal sewage farm soil that I referred to first of all; there you find, perhaps, 12 to 15 inches of soil, and the rest gravel and sand mixed. Now if you dig out a cubic yard of that, and you re-arrange the particles, taking out the large ones and taking out the very small ones, I am quite positive that that cubic yard will do more work after the re-arrangement than it would in its natural state. I would try to illustrate my principle in that way; and if you substitute, instead of your cubic yard of gravel, a cubic yard of other material which will effect the same purpose, you get this concentrated treatment; you can do more work, there is no doubt about it, by an artificial filter than you can on a natural soil." [Crimp, 1623.]

"As to artificial filters, do I understand that if the area of filters is sufficient to fill at the rate of 500,000, or half a million gallons per day, that you consider that the same

FILTERS AS GOOD AS LAND—*continued.*

results, as regards purity, would be obtained as from suitable land?—I think that is so." [1780.]

"I have myself shown, by a long series of experiments carried out with Manchester sewage, that artificial filtration can be applied with success to an effluent containing both sewage and manufacturing refuse of all kinds, and varying in its composition even from hour to hour. In proof of this I beg to submit the reports to which I have already referred, and also a table, which I hand in, showing that out of 119 tests on the sewage effluent from 41 sanitary authorities, resulting from artificial filtration, 88 were of a satisfactory character.

Land Filtration.

"One hundred and twelve tests made from thirty-eight sanitary authorities, January to October, 1898.

Effluents that absorbed oxygen:—

Four hours' test from—

0·07 up to 1 grain per gallon	......	86
1 grain to 1·25 ,,	......	8
1·25 grain to 1·5 ,,	......	7
1·5 and upwards ,,	......	11
		112 tests.

Artificial Filtration.

"One hundred and nineteen tests made from forty-one sanitary authorities, January to October, 1898:—

Effluents that absorbed oxygen:—

Four hours' test from—

0·07 up to 1 grain per gallon	......	88
1 grain to 1·25 ,,	......	8
1·25 grain to 1·5 ,,	......	9
1·5 and upwards ,,	......	14
		119 tests.

[Roscoe, *Interim Report*, vol. II., p. 207.]

"The process of contact beds, however, in all these cases, if properly worked, is found to be most effectual for the

Artificial Filtration—*continued.*

purification of the sewage, and, in fact, there appears to be no sewage that, with the aid of a small amount of chemicals and by passing a sufficient number of times through contact beds, could not be turned into water absolutely as pure as that which originally supplied the district producing the sewage. For all practical purposes, however, the passage of the sewage through two contact beds will effect just as much purification as can be effected by the irrigation process on the best of lands." [Latham, *ib.*, p. 271.]

"In your evidence, I think you have told us that the effluents of sewage that passed through two of your contact filters is as good as the best effluent that you have ever had from any land treatment?—Yes; that is so." [4520.]

"And that you feel confident about?—That I feel confident about; because, when tested with the very worst sewage that we have got to deal with, we get these good results. . . . . I do not know any case in which as good a result is not got, and probably better, than by the application to land." [4521.]

"(Chairman): Did I understand you correctly, and do you think that sewage can be purified just as well by artificial means as it can by land treatment?—Yes; that is my opinion." [Dr. Frankland, 10090.]

(See also 3073, 3074, 6900 *et seq.*)

Filters better than Land.

Strong testimony also was given to the effect that the results from filters are better than those from land. Mr. Cameron brought forward a report by Dr. Dupré, Ph.D., F.R.S., on three samples of filtered effluent taken during frost in January, 1897. Dr. Dupré reported as follows:—

"The three filtered effluents are all extremely good . . ."

"They are all three fully equal to average effluents from well-managed sewage farms, while No. 2 is equal to the best of such effluents. They are superior to any of the former effluents received. In my opinion, these effluents might with perfect safety be allowed to run into a very small brook, or even into a ditch, in which they formed the main or sole current." [1913.]

Filters better than Land—*continued.*

"(Chairman): I do not know whether you could give an answer to a very general question, but do you believe that the filtrations through artificial filters can give quite as good results as filtration over land?—Well, I should say better results. [Woodhead, 2989.]

"Better?—I should say better results up to a certain point, in so far that you can concentrate the process, as it were, and induce decomposition and nitrification, and in a shorter period; you can also control the changes better than you can in land filtration. The amount of land required is very large, it requires to be of a special character, and you are, as it were, to a certain extent dependent upon local conditions; whereas with a filter you can put down a definite area, you can give a definite depth, you can keep it working under special and well-controlled conditions, and, therefore, you know exactly what you are doing; whereas in the case of sewage farming, the amount of rainfall, the kinds of crops, and so on, vary so much that you cannot come to any one set of conditions. In a filter you can either modify as required, or have, as it were, a cast-iron form, which will be applicable to all sewage of a definite character and composition. [2990.]

"But do you think that with artificial filtration it is possible to get as good results as the very best results by land treatment?—Yes, if you carry it far enough; quite." [2991.]

"Now, would you be prepared to say, generally, that artificial filtration is in all respects as satisfactory as land treatment?—Undoubtedly; I say it is better." [Rideal, 4186.]

"But that resolution of solids which is the main object of the anaërobic process is practically lost, is it not, in the land treatment?—Yes; and you get it remaining for a very long time on the surface of the land in broad irrigation. [4426.]

"Is that one of the reasons why you consider these septic processes, as they are called, so superior to land treatment?—Yes; there is a very long delay before such solids disappear in broad irrigation. They would disappear quickly if they were buried beneath the surface. [4427.]

FILTERS BETTER THAN LAND—*continued.*

"And if that process has to take place on the surface of the land, would there be risk to the stream on the occasion of heavy rainfall washing the material into it?—It washes it off the surface of the land into the stream untreated." [4428.]

"The ordinary land filter would not pass and purify sewage at the rate at which the Friern Barnet filters pass it and produce anything like the same results as to purification, as in land filters the nitrifying organisms really only occupy the upper portion of the filter; whereas if a porous filter is constructed every portion becomes the abode of the nitrifying organisms." [Latham, *Interim Report*, vol. II., p. 271.]

"(Colonel Harding): I see that your experience enables you to express a strong opinion as to the possibility of good results being obtained by passing sewage through contact beds. You think that if it was passed through a sufficient number that you could actually restore the original purity of the water which supplied the district?—There is not the shadow of a doubt about it." [4552.]

"(Colonel Harding): Where you have previously withdrawn almost the whole of the suspended solids from a sewage, do you not find the purification over artificial filters is more rapid and more certain than over land?—Oh, yes, I agree with you there; that if you can give an artificial filter a definite quantity of work to do, that it represents our best condition of dealing with sewage." [Strachan, 7755.] (See 7626.)

"I find myself—and it is rather a curious thing—that the effluents from land were more likely to decompose than the effluents from double contact filters, taking the amount of organic constituents in the same as equal. That has apparently been an undoubted experience of mine." [T. E. Hill, 9091.]

"And you think, therefore, that by scientific dealing with the question of sewage treatment on artificial beds it is possible to obtain more perfect results than by land, or as perfect results upon very much smaller areas?—On a much smaller area, yes." [Dr. Frankland, 9952.]

The superiority of filters to land as regards the quantity of sewage dealt with is also pointed out by the Officers to the Commission in their General Report. [P. 318.]

Identity of Filters and Land.

Other witnesses, again, held the view that there is no fundamental distinction to be drawn between filters and land:—

"Then the action of land in purifying sewage is of the same character, is it not, as the action of an intermittent artificial filter?—Precisely the same action; the purification is effected, as of course we all know now, by means of organisms which exist in vast numbers. [Crimp, 1657.]

"Then, as Mr. Killick just now suggested, the improved surface at Wimbledon is in the way of artificial filtration?—I think it is a perfectly correct phrase to apply to it. [1658.]

"Then it is an artificial filter from which you obtain crops?—That is so. [1659.]

"Then by carrying the matter a little further you reach the artificial filter minus the cropping?—That is so, again. You get to the point when your crops will not take the liquid that you have to apply in the case of concentrated filtration on an artificial filter. [1660.]

"So that the relation of the artificial filter to ordinary land filtration is extremely close?—I think it is very close." [1661.]

"It is important, however, to remember that the bacterial processes are not novel, but are identical with those which obtain in nature, so that effluents from sewage farms are strictly comparable with filtrates obtained after either a 'coarse bed' or an anaërobic treatment." [Rideal, 4148.]

"(General Carey): In fact, there is very little difference between a plot laid out for an intermittent downward filtration and an artificial filter?—The material is different. [Dr. Wilson, 6188.]

"The concentration of sewage is rather more in the one case than in the other?—It is, if one may call it so, a natural artificial filter." [6189.]

"And artificial filters and land process are the same process over a large area and smaller; that is your view?—I am taught it, and I believe it." [Strachan, 7757.]

"In comparing land filtration and artificial filtration, do you think that there is any advantage either in the one or the other?—Both processes are substantially the same, in

IDENTITY OF FILTERS AND LAND—*continued.*

> my opinion; only that, of course, in the case of artificial filtration a much larger amount of purifying work can be performed on a given area; but the two processes are identical." [Dr. Frankland, 9936.]
>
> "Are the chemical changes which take place in the purification of sewage on land precisely the same as those by the bacterial process?—Yes; I take it that they are exactly the same, because the effluent is chemically, at any rate, undistinguishable in the two cases. [10,075.]
>
> "The purification is merely at a slower rate?—You mean in the case of land? [10076.]
>
> "In the case of land?—Yes. [10077.]
>
> "That is all the difference?—Yes, I imagine that to be the only difference." [10078.]

The divergence of views revealed by the last few pages would be startling, were it not for the reflection that there are filters and "filters," and land and "land." There can be little doubt that the ideas called up by these two words were very different with different witnesses; and where filters were spoken of with disfavour it is probable that the mere straining filters of hopelessly inadequate area which were formerly used in connection with chemical precipitation have been present in the mind of the speaker.

UNIFORMITY OF RESULTS.

It is admitted on all hands that a biological filter is capable of yielding effluents of a very high degree of purity. The composition of these effluents, however, varies, and this variation has inspired a doubt as to the reliability of the processes by which they are produced.

> "The variations in amounts of ammonias in the effluent, and the differences in degree of conversion of organic matter into nitrates, were shown to be very considerable; nor did it appear clearly to what those variations were to be attributed." [Thomson, 1391.]

Desirable as it may be that the effluents from sewage works should attain a constant standard of purity, the fluctuations in the strength of the sewage and the changes in the conditions which affect the operation of the works are bound to tell in the results.

UNIFORMITY OF RESULTS—*continued.*

That this does not arise only in connection with biological filters was clearly demonstrated at the Exeter Inquiry by Dr. August Dupré, Ph.D., F.R.S., who produced diagrams showing that tho fluctuations in the quality of tho effluents from the Exeter works were far less violent than those which occur in land effluents. He added that "the method employed at Belle Isle has this further considerable advantage over a sewage farm, that *it is far more completely under control* than any sewage farm can be," and that "it is practically independent of seasons and rainfalls." [*Evidence, Local Government Board Inquiry, Exeter,* 1897.]

"It must be added that effluents from artificial filters are more liable to vary than from treatment upon a considerable area of land." [Naylor, 833.]

"You may go one day to an artificial filter and get an exceedingly good result; another day, probably, from some causes that are uncontrollable, you will not get such a good result. The same thing applies to land, perhaps not due to the same causes; it may be due to flooding, or the land may have become saturated." [930.]

"And, also, I gather from your evidence, that you find the result on the sewage produced by land treatment varies very much?—It does. [963.]

"It varies more than you would have expected, probably? —I said the effluents varied. Of course, varying effluents may be due to other causes than the direct effect of the land; they may be due to ground water, or to rain in the case of land, but are not so likely to be due to the same causes as in the case of artificial filters. [964.]

"Of course effluents are exposed to more accident in that way, but practically you do find that an effluent, which is treated only by land, varies much in its quality?—It does." [965—970.]

"Now do you agree with what was told us yesterday, that the results of land filtration are very uncertain, that you find a good effluent at one time and a bad one at another?—I think not, my lord, granted that the land is good and plentiful. The results are very uncertain on different farms owing to the nature of the soil, and very often to the nature of the sewage treated. But given a farm with good soil and plenty of it, so that the sewage can be

UNIFORMITY OF RESULTS—*continued.*

changed from one part of it on to the other as necessary, then I think the results are usually pretty much the same. It is a matter of management." [Dr. Wilson, 1013.]

"On that might I just ask you, when you say you have got good effluent from your land treatment, is the effluent good all the year round?—Yes, so far as we are able to trace it, the effluent is good all the year round." [Roscoe, 3512.]

"The effluents from Harrogate sewage works vary enormously in purity, being sometimes very satisfactory and sometimes nearly as bad as crude sewage; the results depending entirely on the attention to the distribution of the sewage upon the land." [Dr. Wilson, *Interim Report*, vol. II., p. 314.]

(See 6086, 10004.)

LIMIT TO WORK DONE BY LAND.

The reason assigned by Mr. Scudder for the preference which he expressed for land treatment is worth noticing:—

"(Chairman): You say 'so far as chemical results are concerned, land filtration is superior to artificial filtration.' You feel clear about that?—Oh, yes, I think there is no doubt about that. But I should like to explain a little more extensively my meaning. If you have 10 gallons of sewage to purify, there is no doubt the most efficient way to purify that 10 gallons is by filtration through land. [Scudder, 515.]

"Yes?—It gives the best result. But you can also purify that ten gallons through artificial filters, but in no case of artificial filtration can you get results equal to those produced by land. When you come to reflect, it is very easily seen why. The land filter is more compact, it holds the sewage, but will not allow it to go through rapidly. The consequence is that by slow percolation it gets into the conditions which the Massachusetts Board of Health and chemists have shown to be essential for efficient filtration. The land is almost like a carriage with a brake upon it.

LIMIT TO WORK DONE BY LAND—*continued.*

You cannot force it through; it will stop before it will fail, consequently land is preferable to artificial filters." [516.]

"The great advantage that an artificial filter has over a land filter bed is that it can pass a larger volume of effluent through, and it can obtain a result which, in my opinion, is satisfactory, but that result is not equal to the result obtained by land. [763.]

"Then why not?—*Simply because, in the case of land, you cannot force the volume of effluent through the land.* [764.]

"Yes, but I am assuming that the artificial filter is not forced; that you limit the volume on the artificial filter strictly to what is right and proper?—Yes; well, then it would depend on the land. If you were to put ten gallons on a land filter, you would get a very high purification; if you put ten gallons on an artificial filter, it would depend on the relationship and the porosity, closeness of the filter (*sic*). If it was an open filter you would not get the same purification as with a close filter. [765.]

"But do you not think that, theoretically, you could get the same results by artificial filters as from land filtration, seeing that artificial filters are an area specially prepared for the purpose?—You see, if you make an artificial filter, and you make it more porous, capable of taking more water through than a land filter is capable of, you cannot get from an artificial filter area as good an effluent as from land filtration; it depends on its closeness." [766.]

The foregoing evidence was referred to by the Chairman of the Commission in his examination of Mr. Santo Crimp:—

"One witness whom we had before us said that . . . . no artificial treatment was as thorough as land, because you could not force the thing through land, whereas you could force it through any artificial filter?—It is perfectly true that you cannot force it through land, but what he can do, and what is done in some cases, is to force the excess which will not go through the land into the river untreated, and that is where the trouble arises." [1624.]

There is no apparent obstacle to the construction of a filter so compact that it will resist the passage of sewage, just as land

Limit to Work done by Land—*continued.*

does, and produce a like brilliant effluent; but no ono apparently has thought it worth while to make a filter in this way. In the case of filters, it seems to be held that it is of more importance to cope with the *whole flow* of sewage, and turn out a reasonably good effluent, than to produce a small quantity of exceptionally good filtrate, and allow a large part of the sewage to run off the surface without adequate treatment. The practical view of the matter is well put by Dr. Fowler:—

> "By giving thorough consideration to the conditions existing at and near the point of discharge, the necessary degree of purity for every case should be capable of being exactly assessed, and thus tho limit of necessary expenditure defined. For in my view the sewage problem is essentially a cost problem.
>
> "*It is comparatively easy in the light of our present knowledge to purify sewage to any degree of purity provided cost does not enter into the question. The true solution is to purify sewage to well within the limits of safety for any given set of conditions at the lowest possible cost.*" [Manchester Lecture, p. 21.]

It should be borne in mind also that the comparisons above referred to were made between systems which were as yet in their infancy, and one in which the results of thirty years' experience were available. We may therefore expect that any future comparisons which are made will be more favourable to the artificial filter, especially if, in considering the results from sewage farms, regard is had to the whole flow, and average rather than exceptional farms are taken for comparison.

Dependence on Management.

The question of management received full attention at the hands of the Commissioners, and several witnesses were questioned as to the relativo dependence of filters and sewage farms thereon. Several of the opinions elicited were adverse to filters in this respect.

Dependence on Management—*continued.*

"Probably mismanagement of the land does not lead so rapidly to bad results as mismanagement of the artificial filters. [Dr. Wilson, 1015.]

"But of course an artificial filter can be very much more easily managed than the land ?—Well, no, my lord ; I think probably the land is easier to manage, and at any rate, it does not so soon show the results of mismanagement. If there is mismanagement, it spoils the land, there is a silting up of the upper layers of the soil, but that land will soon recover itself." [1016.]

"In my judgment the bacterial plan is not adapted to small places, and land would be vastly superior, as requiring very little attention. The great essential with regard to bacterial treatment must be the proper supervision of it from time to time throughout the day, which cannot be given in small districts." [Latham, 4700.]

"From the experience I have had of them, it seems to me very probable that if biological filters are put into the hands of the ordinary sewage farm manager they will from time to time be misused, as sewage farms have been ; and if they are misused, they will get sewage sick, and will not recover themselves nearly so easily as land areas. In fact, they get clogged up, and will have to be renewed entirely." [Dr. Wilson, 6378.]

"Have you had any experience of bacterial filters ?—I have. [Chatterton, 6483.]

"Do you consider that the same good management is essential ?—I do ; I think that it is more essential ; I think that you require probably a more intelligent man than the ordinary sewage farmer, as I can see he has not got used to bacteria beds yet." [6484.]

"Do you think there is more difficulty in obtaining competent management for one process than the other ?—If a sufficiently large area of land is available, and it is really desired to purify the sewage on that land, because, of course, in many cases there is no real desire even to purify the sewage on the land, then I think that it would not require such careful management as the satisfactory management of artificial beds, because if the sewage is distributed over a

DEPENDENCE ON MANAGEMENT—*continued.*

very large amount of land it cannot get away without these purifying processes coming into play. Of course, it might be so passed through artificial beds that very little purification is really effected unless it was systematically done and properly controllod." [Dr. Frankland, 9937.]

"A small village has to choose which treatment it will adopt, whether it will take an acre or two acres of suitable land, or whether it will adopt bacterial treatment; have you any opinion as to which course they should take?—Well, I think that the land would require less skilled supervision than the bacterial beds. I think that would be an important determining factor in the choice." [10072.]

"I do not think it requires such a skilled man to work land satisfactorily as it would to work beds satisfactorily." [10074.]

Mr. Tatton considered that land and filtors were on the same footing in this respect.

"Of course, that means first-class management?—Yos, that is so. [Tatton, 6782.]

"Of the bacterial treatment?—Yes, that is so. [6783.]

"And you would require for that purpose quite as efficient and competent supervision as you would for a sewage farm?—Oh, certainly you would." [6784.]

The following witnesses held that filters woro the more manageable:—

"My experienco has been that you find very few men who really understand how to apply liquid sewage to land. On the other hand, you can very easily train, and you can very readily obtain men who act almost like machinos. We have mechanism that can do away with the men employed on the sewage filters, and these filters may be worked automatically, and if you have filter beds worked automatically you are more sure of your results." [Scudder, 681.]

"As to the practical working of this process, do you think that the workmen, say, in a rural district could be depended on to open and close tho filters at tho appointed hours?—As a matter of fact they do, and I have found this, that these men, if thoy have somo process to work with which they cannot give good results, get dishoartened, and they are not

Dependence on Management—*continued.*

perhaps quite so careful as they might be. I have known that with the old precipitation schemes. They would give almost anything to get rid of it, but with these beds, and with anything of this kind, it is like a man with a good engine, it is astonishing what pride they will take in their work when they begin to get results which are really satisfactory and the thing is going along comfortably; these men will really take such pride in their work that they do not care what they do, just like a good engine driver will take care of his engine. [Dibdin, 4012.]

"If the thing is not properly supervised the whole thing would be probably a failure?—There is no objection to applying some automatic method of charging the beds if it is considered necessary; that is a matter of detail. I do not deal with that; that is an engineering question." [4013.]

"Are we to gather from what you have just now told us that you think it is more easy to maintain in efficient working order an artificial area, such as your bacteria beds, than a natural area of land, such as that you are using for part of your sewage?—Yes." [Pickles, 15373.]

"You have no doubt about it?—No doubt about it." [15375.]

The heart of the matter lies in the following questions put by Colonel Harding to Dr. Frankland:—

"And artificial filters would be more under control, would they not, than land; under more ready supervision than land areas, because of their smaller area?—Yes, certainly, you could have them under more immediate supervision than large areas of land. [Dr. Frankland, 9953.]

"But your suggestion that in connection with land there is a temptation to exaggerate the volume which is being dealt with on a given area, surely does not apply to land treatment only; it applies equally to artificial filtration, does it not?—Oh, of course there might be the same temptation on beds. [9954.]

"Exactly the same?—Well, not exactly the same, because in the case of land it is so frequently the case that they wish to derive a profit from crops on the land. Now there is no temptation of that kind. [9955.]

"But in so far as they want to have crops, they will not

Dependence on Management—*continued.*

exaggerate the volume they are dealing with on the land, but rather the other way, will they not? That is another point. They would rather deal with less sewage and let it flow—the temptation in that case is to let it flow—direct to the stream untreated rather than to put too much on the land?—Well, of course that is what one frequently sees at sewage works." [9956.]

"And you consider it an advantage of artificial filtration that, having nothing to do with crops, that kind of temptation does not arise?—Yes, I think that is a great advantage." [9958.] See also pp. 308, 319.

The greater amenability of artificial filters to control, to which Dr. Frankland calls attention, has also been pointed out by Dr. Sims Woodhead (Answer 2990, p. 272) and Dr. Dupré (p. 276).

There can be no doubt that the management of a bacterial installation can more readily be reduced to a routine, and therefore makes less demand upon the intelligence and initiative of a manager than that of land. The introduction of automatic machinery, moreover, has rendered it possible to regulate the working even of the smallest installations with a precision and readiness to respond to variations in the flow which could not be expected from an attendant.

Influence of Frost on Purification.

It has already been shown (pp. 31, 32) that the purification of sewage upon land is not interfered with to any material extent by the cold of an ordinary English winter, and the good working of the contact beds at Exeter during a hard frost is referred to on page 271.

A bacterial filter possesses several advantages over land in point of resistance to frost. In the first place, the texture of the material of which it is composed is much more open, rendering it a worse conductor of heat. Secondly, it is, as a rule, deeper than the active layer of the soil. Thirdly, each cubic foot of filtering material deals with a larger quantity of sewage, and consequently receives more warmth therefrom than a cubic foot of soil. Fourthly, the liquid, being delivered in bulk to a contact bed, is not chilled as it is in flowing over the surface of a sewage farm. A trickling filter on to which the sewage is

showered through the air has no advantage over land in this respect. See also p. 309.

Effect of Purification Processes on Disease Germs.

See also p. 303.

No comparison of modes of sewage treatment is now regarded as complete which does not take account of their influence on disease germs; but the evidence on this point is still too incomplete and conflicting to warrant any definite conclusions thereon. It may suffice here to refer to a paper on "The Viability of the Enteric Bacillus in Soil and Sewage," read by Major R. M. Firth, R.A.M.C., in 1902 at the Manchester Congress of the Sanitary Institute. The author mentioned that while both land effluents and those from bacteria or contact beds "contain large numbers of typical sewage organisms," the germs of the chief water-borne disease, namely typhoid, were capable of "surviving in ordinary and sewage-polluted soil for periods varying from fifty-three to sixty-five days."

Among those who took part in the discussion on the paper was Dr. Rideal, who pointed out that:—

> "Those who advocated bacterial methods knew that while land effluents frequently contained large numbers of typhoid and coli organisms, the evidence that the effluent from bacterial methods was as bad was not nearly so strong." [*Journal San. Inst.*, vol. XXIII., p. 617.]

This statement of Dr. Rideal's may seem at variance with that made by the Commissioners in paragraph 21 of their Interim Report, and quoted on page 293; but it will be seen that the Commissioners referred to "land of a kind suitable for the purification of sewage," while Dr. Rideal probably had in mind the actual condition of the generality of sewage farm effluents.

Artificial Filters should be Accepted.

The evidence which has been considered in the foregoing chapters discloses a strong body of opinion to the effect that sewage can properly and efficiently be disposed of otherwise than by treatment on land, and it is agreed on all hands that other processes should now be accepted.

> "The experiments on a considerable scale which have been made by Sir Henry Roscoe at the Manchester Works, by Mr. Dibdin in London, and by Mr. Corbett in Salford, clearly demonstrate the possibility of treating the sewage of

ARTIFICIAL FILTERS SHOULD BE ACCEPTED—*continued.*

large towns by artificial filtration if a sufficient area of filter beds be used. . . . .

"The reasonable view to be taken of the mattor seems to bo that instead of any hard-and-fast rule being laid down, each case should be treated on its own merits: that if suitable land can be obtained it should be used, but that if it cannot be got artificial filters should bo sanctioned, but with stringent restrictions as to the volume of sewage allowed on a given area." [Tatton, 259.]

"More recent experience has in no way altered the conclusions come to twelve months ago, and I would venture to suggest that the requirements of the Local Government Board should be modified, so that in cases where it is proved that suitable land cannot be obtained filtration may be sanctioned. [261.]

"It would seem more advisable in these and similar cases that the Board should sanction schemes including artificial filtration, instead of insisting on land when the use of it is doomed to failure." [262.]

(Quoting Sir Henry Roscoe): "Artificial filters are a move in the right direction, especially in the case of large towns having difficulties in acquiring sufficient area of land and of a suitable character for the purification of its sewage. Manchester and Salford are instances where artificial filters might be adopted with advantageous and satisfactory results." [Scudder, 505.]

"Although in the past I have looked upon filtration of sewage, otherwise than through land, as of partial and limited value, I strongly believe that the death knell of the costly sewage farm has been rung; and, what is of far more importance from an economic and sanitary sense, the problem of sewage disposal has been at last solved, and the prevention of pollution of our rivers and streams has become, not only possible, but practicable." [Dr. A. Bostock Hill, quoted by Garfield, *Interim Report*, vol. II., p. 196.]

"What I do say is this: that with suitable land and a limited quantity of sewage effluent, say a maximum of 60,000 gallons per acre—for in both cases I am supposing, as I told Sir Richard Thorne just now—the preliminary settlement by chemical treatment in tanks has been adopted, land filtration can be excellent; but where large quantities

Artificial Filters should be Accepted—*continued.*

of sewage have to be treated, and where the necessary area of land is either insufficient or unsuitable, there artificial filtration, at a maximum rate of 800,000 gallons per acre, can with success be resorted to, because the area needed is very much less than is required for land filtration to obtain a good result." [Roscoe, 3545.]

"(Chairman): Have you anything to say about the present land requirements of the Local Government Board?—Of course I recognise that they have been wise in the past, and the knowledge that we have to-day they had not a few years ago; but I think where the land is unsuitable, that if the Board could see their way to have an adequate area of filter in the place of land, it would be a very great advantage generally." [Barwise, 4038.]

"In all cases where there is a difficulty in acquiring land, or the lands are not suitable for the purposes of irrigation or land filtration, the bacteria bed system offers a complete solution for the purification of sewage." [Latham, 4505.]

"Since that time" (1874), "I ought to mention, there has been another process, and one only in which I myself have confidence for the purification of sewage, and that is the bacterial treatment of it in tanks. I have had some little experience of this process, and the results, so far as I have gone, show that it is capable of very efficient application to sewage. [Sir E. Frankland, 3073.]

"Without treatment on land?—Without any treatment upon land." [3074.]

"Then do you consider that that recommendation of the Royal Commission of 1868 should be modified at present, as to the use of land for the purification of sewage?—Yes, but I think where sufficient land is available, where land is available at a sufficiently cheap rate, I should still prefer the land treatment; because you utilise, for the benefit of the community at large, the fertilising constituents of the sewage, and, of course, it is all lost by the septic treatment. That is an economical rather than a chemical question." [3081.]

Sir Edward Frankland's opinion will be received with the respect due to that of the sole survivor of the Royal Commission on Rivers Pollution, upon whose findings the practice of the Local Government Board has been so largely founded. It will

be seen that the preference which he expresses for land is based, not on considerations connected with the purification of the sewage, but on the desire to utilise its fertilising constituents "for the benefit of the community."

The modes of treatment which are now in favour with well-nigh everyone concerned with the disposal of sewage may yet result in a fuller realisation of the manurial value of the sewage than has ever been possible in the past.

The salient point of Sir Edward's answer is that he regards the progress which has been made of late years in the purification of sewage as sufficient to justify the modification of the recommendation which he helped to frame twenty-seven years before.

The view of the position taken by the present Commissioners is summed up in their second conclusion :—

Conclusion 2.

> "After carefully considering, however, the whole of the evidence, together with the results of our own work, we are satisfied that it is practicable to produce by artificial processes alone, either from sewage or from certain mixtures of sewage and trade refuse (such, for example, as are met with at Leeds and Manchester), effluents which will not putrefy, which would be classed as good according to ordinary chemical standards, and which might be discharged into a stream without fear of creating a nuisance.
>
> "We think, therefore, that there are cases in which the Local Government Board would be justified in modifying, under proper safeguards, the present rule as regards the application of sewage to land.
>
> "No general rule as to what these safeguards should be can be laid down at present, and indeed it will, probably, always be necessary that each case should be considered on its own merits." [*Interim Report*, p. x.]

The thirty-first Annual Report of the Local Government Board (for the years 1901-2) refers to the Interim Report of the Commissioners as follows :—

> "During recent years numerous artificial processes for

Report of Local Government Board—*continued.*

the treatment of sewage have been submitted to us by local authorities. These processes are now under the investigation of the Royal Commission on Sewage Disposal, and our knowledge of their value and limitations is at present incomplete.

"The Commission have, however, issued an Interim Report expressing the general conclusion that it is practicable to treat sewage by artificial processes alone so as to produce an effluent which will not putrefy, and they indicate that there are cases where the land available is unsuitable for the treatment of sewage, is too limited in extent for the purpose, or is only obtainable at a prohibitive cost, in which we should be justified in modifying, under proper safeguards, the rule as regards the application of sewage to land.

"In the present incomplete state of our knowledge it is not possible to lay down rules as to what these safeguards should be, but it seems to us clear that for the proper working of these artificial processes skilled supervision is necessary, and that the plant required to deal with a given volume of sewage is considerably larger and more costly than was at first supposed to be necessary.

"The treatment of sewage by these artificial processes must to a certain extent be regarded as experimental, but having regard to this Interim Report, we have felt justified in cases such as those which the Commission indicate, in sanctioning loans for the treatment of sewage by artificial processes alone." [Annual Report L. G. B., 1901—2.]

The relaxation of the rule relating to land has been a great boon to the local authorities who have benefited thereby, and has removed the most serious obstacle to the purification of the rivers of this country.

It is natural that other authorities who have not received the same indulgence at the hands of the Board should think that the latter might have placed a more liberal interpretation upon the findings of the Commissioners. It is perhaps natural, too, that the Board, with a lively sense of the responsibility of their position, should hesitate to break all at once with the traditions which have guided them in the past. If such be their attitude, fuller experience of the new methods may be expected to have its due effect.

Some speculation has been indulged in as to what the Commissioners meant by "proper safeguards," and whether they thought it desirable that land should still be provided, though possibly in reduced area, in every case in which it was obtainable.

In considering the burden which the insistence on land treatment has laid upon local authorities, it is not sufficient to take into account the price of tho land and the incidental costs incurred in acquiring it and laying it out, for the influence of the requirement in question only too frequently pervades a whole scheme of sewerage and sewage disposal. The first point which an engineer has to settle in preparing such a scheme is where and how the sewage shall be disposed of. In order to find the prescribed area of land, the sewage has often to be carried much further than would otherwise be necessary, entailing a long and costly outfall sewer. Not only so, but in order to command the land it must be delivered at a high level. This may mean, in the more fortunate cases, nothing worse than flatter gradients, and consequently in some of them larger sewers, than would otherwise be necessary, and the curtailment of the fall available for the purification works; but in others, less favourably situated, pumping, with the initial cost of a pumping station, machinery, and rising main, and the unending expense of fuel, labour, and upkeep, must be resorted to.

Local authorities—at all events the more intelligent ones—will not shirk any expenditure the need for which can be made clear to them; but it is not unnatural that they should dislike to be compelled to provide land in connection with their schemes of sewage disposal when this has to be done, not with any expectation that it will be of use in the purification of the sewage, but for the sole purpose of being offered as a sacrifice to propitiate the Local Government Board.

CHAPTER XVII.

OTHER ASPECTS OF THE PROBLEM.

The sewage problem has certain other aspects which are of great practical importance, and concerning which much valuable evidence has been collected by the Commissioners, but which the writer does not propose to discuss at any length here. The general character of the inquiries which the Commissioners have been prosecuting, and the conclusions at which they have arrived, may, however, be briefly indicated.

Standards of Purity.

A desire has often been expressed that standards should be laid down defining "polluting liquids," and establishing limits of impurity to which sewage effluents should conform. The Rivers Pollution Commissioners appointed in 1868 recommended certain definitions of polluting liquids, the first three of which relate more particularly to sewage:—

> "(a) Any liquid containing, in suspension, more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter, in 100,000 parts by weight of the liquid.
>
> "(b) Any liquid, containing in solution more than two parts by weight of organic carbon, or 0·3 part by weight of organic nitrogen, in 100,000 parts by weight.
>
> "(c) Any liquid which shall exhibit by daylight a distinct colour when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel." [Sir E. Frankland, 3002.]

These standards were not embodied in the Public Health Act of 1872, and a subsequent attempt (made in 1873) to establish a legal "scale of definitions of polluting liquids" proved abortive. No standards of the kind have yet been established by law.

STANDARDS OF PURITY—*continued.*

The Commissioners went very closely into the question of the advisability of adopting such standards, and the majority of the witnesses whom they examined on the subject were of opinion that it was either undesirable or impracticable to do so. It is significant that this view was not confined to those who, in their private or corporate capacity, would have to comply with any standards which might be adopted, but was fully shared by the representatives of the Rivers Boards, for whose assistance, in preventing tho pollution of rivers, legally defined limits of impurity might have been thought desirable.

The following opinion, expressed by Mr. Scudder on this point, is fairly representative of those held by other witnesses:—

> "Then with regard to the second portion of the question, 'whether I think standards are advisable,' I think thoy aro not advisable. I have given a considerablo amount of attention, and I have always endeavoured to see if it was possible to get at a workable standard. That I have not been able to do, and I think that each caso ought to be tested on its merits. To lay down absolute standards of purity for every river would bo a mistake, irrespective of the locality and circumstances of the case." [Scudder, 689.]

Dr. Wilson has advised the West Riding Rivers Board that it is "impossible" to adopt fixed standards. [1196.]

Even those who expressed a desire that a standard of purity should be suggested by the Commissioners did not in all cases consider that this should have the force of law:—

> "Would you like to see this Commission suggest any standard of purity for an effluent which was to go into streams that are not used for drinking purposes or for washing purposes?—Yes, my lord, even if it were not published as a hard-and-fast standard, I think it would do a great deal of good if they expressed an opinion as to what a satisfactory effluent should be." [Barwise, 4054.]

See 821, 3001, 5993, 6020, 6050, 6088, 7476, 7803, 7889, 9102, 257, 485, 501 . . ., 686 . . ., 923, 1306 . . ., 1364 . . ., 1811 . . ., 2423 . . ., 3510, 3678, 4160, 7594, 8958, 9075, 9819, 10048 . . ., 12166. The question is also dealt with on pp. 321, 322.

A consideration which is too often overlooked is that standards of purity are not a goal in themselves, but merely a means to an

STANDARDS OF PURITY—*continued.*

end. This is pointed out by the Manchester Experts in their report:—

"Indeed it should be clearly borne in mind that the limits of impurity must not be too rigidly interpreted, and that the object of purification is primarily the production of an effluent free from putrescibility, and not one in which the chemical ingredients are below some necessarily more or less arbitrary standard." [*Manchester Experts' Report*, p. 31.]

The same feeling found forcible expression from Mr. Strachan:—

"I have a very strong opinion upon that point, that our sole duty from the health point of view is to turn out an effluent that causes no nuisance or injury or annoyance in the river into which it goes. Fixed standards I hold in abhorrence." [Strachan, 7557.]

That the Commissioners themselves set out with the same common-sense view of the matter is shown by the wording of the second question propounded in their Interim Report:—

"Is it practicable uniformly to produce by artificial processes alone an effluent which shall not putrefy, and so create a nuisance in the stream into which it is discharged?" [*Interim Report*, p. ix.]

Hardly less significant are Dr. Voelcker's observations with reference to the suggestion that some simple method might be devised whereby a works manager could test the quality of his effluent:—

"I should be very sorry to try to make chemists out of them. I think the ordinary indications of freedom from matter in suspension and freedom from smell are about as good ones as either he or a chemist could have. [Voelcker, 10245.]

"Even speaking as a chemist, I should attach more importance to the observation of my eyes and my nose as to whether it was a pure and proper effluent than as to whether it contained this or that number of grains per gallon of this or that constituent." [10246.]

The Officers of the Commission, however, consider it desirable that managers should subject their effluents daily to some simple chemical tests (p. 320). A method of water analysis has lately been introduced by Dr. J. C. Thresh, M.D., D.Sc., D.P.H., Medical Officer of Health for Essex, in which "soloids," containing known quantities of the necessary re-agents, are substituted for the standard solutions generally used. This system,

though primarily designed for the use of Medical Officers, is so simple, demanding no previous experience of laboratory work, as to be capable of use by any reasonably intelligent man; in fact, Dr. Thresh, in the preface to the second edition of his treatise on the methods in question, expresses the hope that they will prove of service to the managers of sewage works and others.

Bacteriological Qualities of Effluents.

Sewage Effluents in Relation to Disease.

A grave note was sounded by the Commissioners in the following passage of their Interim Report:—

> "20. As we have already said, sewage effluents must, in accordance with present knowledge, be judged not only from a chemical, but also from a bacteriological point of view. In order to safeguard public health, it is, in certain cases at any rate, not enough to know the chemical features of an effluent, and to ascertain that it will not putrefy of itself; we must know the bacteriological features as well.
>
> "21. Several witnesses have referred to the danger of allowing pathogenic organisms to enter streams which are used for drinking purposes, and our own officers are carrying out careful prolonged investigations on this matter.
>
> "We are impressed with the great importance of the bacteriological questions which have arisen in the course of our inquiry, but we do not at present feel justified in putting forward any conclusions concerning them.
>
> "We may, however, even at this stage point out that, as a result of a large number of examinations of effluents from sewage farms and from artificial processes, we find that, while in the case of effluents from land of a kind suitable for the purification of sewage there are fewer micro-organisms than in the effluents from most artificial processes, yet both classes of effluents usually contain large numbers of organisms, many of which appear to be of intestinal derivation, and some of which are of a kind liable, under certain circumstances at least, to give rise to disease.
>
> "We are of opinion, therefore, that such effluents must be regarded as potentially dangerous, and we are considering whether means are available and practicable for eliminating or destroying such organisms, or, at least, those giving rise to infectious diseases." [*Interim Report*, p. x.] See also pp. 303, 304, 322.

Bacteriological Qualities of Effluents—*continued.*

The Interim Report was followed (on 7th July, 1902) by a Second Report, consisting wholly of a series of reports by the Officers of the Commission, relating almost exclusively to the influence of bacterial processes upon disease germs. This report, in conjunction with the statements in the Interim Report quoted above, caused great consternation among those concerned with the purification of sewage, who regarded them as possibly foreshadowing new requirements which, by reason of the difficulty of complying with them, might postpone indefinitely the restoration of our rivers to a state of tolerable purity. Recent outbreaks of disease caused by sewage-polluted oysters have forcibly drawn attention to the risk attached to the unregulated discharge of crude sewage, and highly coloured statements have been circulated as to the danger which is alleged to lurk in bacterial effluents. It has even been seriously suggested that all effluents should be sterilised before discharge, overlooking the obvious consideration, which has been well pointed out by Dr. Reid, that sterilisation, to serve its purpose, must be carried out not only on the dry-weather sewage, nor on the three volumes of storm sewage which are dealt with in the purification works, nor even on the six volumes which the Local Government Board require to be treated; but that it would be necessary to sterilise the whole of the surplus storm water (over and above the six volumes) received at the purification works, and to place a sterilising plant on every storm overflow which exists in the whole system of sewers. [See *Journal San. Inst.*, vol. XXIII. p. 617.] This practical consideration is recognised by Dr. Houston in his Bacteriological Report referred to on p. 322.

So seriously was the situation regarded that a sessional meeting of the Sanitary Institute, held on 11th March, 1903, was devoted to its consideration. The discussion was opened by Dr. George Reid, Medical Officer of Health for Staffordshire, with a paper expressing keen disappointment that it should be contemplated to add to the difficulties already experienced by local authorities in dealing with their sewage by compelling them to render it bacteriologically pure. Dr. Reid's observations were strongly supported by those who took part in the discussion. The meeting was presided over by Colonel T. Walter Harding (himself a member of the Royal Commission), who reminded those present that the reports embodied in the Second Report of the Commissioners were merely those of the experts retained by

Bacteriological Qualities of Effluents—*continued.*

them, and did not bind them in any way. [See *Journal San. Inst.*, vol. XXIV., pp. 90 *et seq.*]

The non-medical reader of these reports, whose duties compel him to have regard to the bacteriological as well as the chemical quality of an effluent, will doubtless be dismayed by the extreme diversity of opinion which they disclose. In this, as in most matters, however, the conflict of evidence is more apparent than real, being largely accounted for by variations in the conditions under which different experimenters carried on their work. It seems to be demonstrated, if demonstration were necessary, that none of the processes now in use can be relied on absolutely to free the sewage from the germs of disease, and that 100 per cent. of purification is no more to be expected on the biological than on the chemical side. Those who, like the writer, are concerned with the matter from a practical rather than from an abstract medical point of view, will turn with relief from recitals of gallant attempts to enumerate the real or suspected pathogens in sewage effluents to Dr. Reid's declaration, that if he had to choose between "the discharge into a stream of the crude sewage of 29,000 people" and that "of the treated, therefore non-putrefactive, sewage of a population of 420,000 odd," all he could say would be, "it would not be the crude sewage of 29,000 people which he should select in the case of a stream over which he had control as an alternative to the treated sewage of a population, no matter how large." [*Journal San. Inst.*, vol. XXIV., p. 94.] This common-sense view of the case is the more significant in that Dr. Reid was by no means oblivious of the possible presence of disease germs in an effluent.

Happily, the purification of sewage has now been carried on long enough to show whether or not an effluent of the kind hitherto accepted as satisfactory is, in practice, found to communicate disease; and, as Dr. Rideal tersely observes, "it is the pathogenicity of such filtrates upon which evidence is wanting." [4148.]

Those who are disposed to suspect the Commissioners of a desire to involve local authorities in enormous expense in guarding against dangers which, whether real or imaginary, have yet to be demonstrated, may find some re-assurance in the observation of Sir Richard Thorne upon Dr. Rideal's statement, that "it is quite possible to make all effluents suitable

for drinking purposes." [4398.] "*Possibilities*, yes; but we have to think of *practicabilities*." [4399.]

The same spirit is manifested by the Commissioners in the third conclusion of their Interim Report :—

Conclusion 3.

"30. We consider it of the utmost importance that the simplest possible means should be provided for adequately protecting all our rivers, and we are further of opinion that it will be desirable, probably for some time to come, that scientific experiments should be carried on in order to ascertain all the real dangers of pollution against which they should be protected.

"In the present state of knowledge, and especially of bacteriology, it is difficult to estimate these dangers with any accuracy, and it seems quite possible that they should be either exaggerated or undervalued according to the predisposition of those who have to deal with them. An authority, guided by medical considerations, might not unnaturally be inclined to insist on a degree of purity which may ultimately prove in certain cases to be uncalled-for, while another authority, with its mind fixed upon economy, might shrink from taking essential precautions." [*Interim Report*, pp. xii., xiii.]

Provision to be made for Storm Water.

This branch of the general question received due consideration at the hands of the Commissioners and their Officers, and is discussed by the latter at some length in their General Report (pp. 305, 310 . . ., 322.

Much evidence was collected alike as to the volume and frequency of storm flows and their condition at various stages of a storm. The extreme foulness of the first rush of storm water was mentioned by several witnesses, whose evidence shows that the common practice of making an overflow dependent on the rate of flow in the sewer at any moment is open to grave objections. As the writer does not propose to go into the subject here, he may mention that it is fully dealt with in

papers read by Mr. Silcock and himself at recent Congresses of the Sanitary Institute. [*Journal San. Inst.*, vol. XVIII., p. 570, and vol. XX., p. 624.]

See 1866, 2126, 4507, 5318, 5402, 5658 . . . 5694, 6191 . . . 6245, 6457, 6666, 7097, 7525 . . . 7547, 7809 . . . 15269, 15473.

THIRD REPORT.

TRADE EFFLUENTS.

The question of dealing with trade effluents is considered in a separate report. The scope of this report (the third) may be gleaned from the following extracts:—

"We find that sewage containing trade effluents is generally more difficult to purify than ordinary sewage, and that the following are the chief causes of difficulty:—

"1. The trade effluents may be turned into the sewer at irregular intervals, so that the composition of the sewage as it arrives at the sewage works varies considerably throughout the day.

"2. The trade effluents may contain large quantities of solids in suspension which tend to choke the purification plant.

"3. The trade effluents may be very acid or very alkaline, or otherwise chemically injurious.

"The general opinion of these witnesses, however, is that it is practicable, in the great majority of cases, to purify mixtures of sewage and trade effluents if the manufacturers adopt reasonable means for removing the solids, equalising the discharge, and when necessary neutralising the trade effluent."

[Harding, 7034-7501; Tatton, 13680, 13727, 13773; Wilson, 14051; Fowler, 14383-9, 14391; Simpson, 11644, 11651-2, 11675-81; Jones, 11789; Beeley, 12244, 12247; Platt, 12315, 12331-6; Stenhouse, 12406-7; Ashton, 12450; Morgan, 12448-9; Johnson, 12599-600, 12652; Hopkinson, 11905, 11923-4, 11972-3; Sharpe, 12034-40; Powell, 12074-5, 12087; Sir B. T. Leech, 14394-5; Dreyfus, 14409-10.]

"Moreover, there is some evidence to indicate that even if the manufacturers do not adopt such means, the purification of the mixture of sewage and trade effluents is still practicable, though the difficulties and cost are much greater.

TRADE EFFLUENTS—*continued.*

"But the evidence clearly shows that wherever practicable the manufacturer should adopt means for removing the bulk of the solids in suspension from his effluent, for neutralising it, and for delivering it into the sewer in a fairly uniform manner. And, further, it would seem probable that in some cases the cost to the manufacturer of adopting these preliminary measures would be less than the additional cost which would be thrown on the local authority if the measures were not adopted. Indeed, there is evidence to show that occasionally the removal of the solids has been a source of profit to the manufacturer.

"We have examined a large number of effluents from works where sewage containing trade refuse is being treated, and our results fully support the view that it is practicable in the great majority of cases to purify mixtures of sewage and trade effluents if the manufacturers adopt reasonable preliminary measures." [*Third Report*, pp. xv., xvi.]

The influence of trade refuse on the purification of sewage on land is referred to by the Officers of the Commission in their General Report. See p. 307.

The Third Report deals also with the involved and conflicting state of the law with regard to the admission of trade effluents into sewers, and contains certain recommendations for facilitating such admission. The necessity for providing machinery for the settlement of differences between local authorities and manufacturers is referred to, and a large number of opinions cited as to the means which should be adopted for the purpose. These are summed up as follows:—

"42. It will be seen that the balance of opinion is strongly in favour of the view that for the settlement of these questions it is necessary to constitute a Central Board possessing adequate technical knowledge, such as the Supreme Rivers Authority which we recommended in our Interim Report. Some witnesses, while agreeing with this view, have expressed the opinion that the questions should in the first instance be referred to the Local Rivers Board, and that the Central Board should be an appellate tribunal only.

"Only a few witnesses consider that the questions can properly be determined by the ordinary Courts.

"43. . . . . The scientific questions to be solved would in most instances be capable of actual determination by a properly equipped Central Authority, and there can be little doubt that such direct proof would be far less costly than the process of endeavouring to arrive at the truth through the evidence of expert witnesses in a Court of Law.

"Moreover, the matters to be determined includo not only scientific questions on which witnesses may be expected to differ, but also considerations of an administrative character which should more properly be dealt with by a Government Department.

"Further, we find that a Central Authority possessing adequate technical knowledge would command the confidcnce of local authorities and manufacturers."

Central Department Essential.

"44. In our opinion, a properly equipped Central Authority is essential, and we unhesitatingly rccommend the creation of such an Authority.

"In the interests of river purification as well as of the trade of the country, we consider it is of the highest importance that the changes in the law which we have recommended should be made. But these changes would not, in our opinion, be of much use apart from the creation of a Central Authority for the determination of differenccs between the local authority and the manufacturer.

"If thc settlement of these diffcrences be left to tho ordinary Courts, differential treatment of manufacturors, with all the objections to it, will be certain to continue.

"45. Thc Central Authority should have the following permanent chief officers :—

"1. An Administrative Head.

"2. A Bacteriologist having spccial knowledge of the bacteriology of sewage, trade effluents, and water supply.

"3. A Chemist having special knowledge of thc chemistry of sewage, trade effluents, and water supply.

"4. An Engineer having special knowledge of geology and water supply.

"It should also be provided with a laboratory.

"46. The officers of the Central Authority must be clothed with the necessary powers to conduct inquiries, to call witnesses, to enter premises to take samples of the trade effluent, and generally to do such acts as are necessary for the proper performance of their duties.

"47. At any inquiries which may be held, neither Counsel nor expert witnesses should be heard except with the special permission of the Central Authority.

"48. The work of the Central Authority will be so intimately connected with the work of the Local Government Board that it will be desirable to make it a new department under the Local Government Board rather than an entirely separate department." [*Ib.* pp. xxiii *et seq.*]

The Commissioners further recommend the formation of Rivers Boards throughout the country, each board being in charge of a district which should—

"include, as far as practicable, the whole of one or more watersheds, and it should be sufficiently large to justify the permanent appointment of a skilled Chief Inspector at an adequate salary. One of the first duties of the Central Authority will be to ascertain what grouping of counties would be most effective, and then to take steps to constitute Rivers Boards for these areas." [*Ib.* p. xxvii., par. 67.]

FOURTH REPORT.

POLLUTION OF TIDAL WATERS, WITH SPECIAL REFERENCE TO CONTAMINATION OF SHELLFISH.

On 28th December, 1903, the Commissioners made their Fourth Report, which is headed as above, and deals exclusively with the matters indicated by the title. Its scope and purport may be gleaned from a couple of extracts:—

"It has been suggested that the evils would be removed if the law were altered so as to require that all sewage should be purified before its discharge into tidal waters. We do not consider that any such sweeping alteration of the law could be justified.

"There are undoubtedly many cases, where shellfish are not concerned, in which the discharge of crude sewage into such waters does not, according to present knowledge, cause

Pollution of Tidal Waters, &c.—*continued.*

any harm, and to require purification in all cases would lead to the waste of large sums of money.

"And even where shellfish have to be considered, such an alteration of the law would not always meet the necessities of the case." [Fourth Report, vol. I., p. xx., par. 33.]

"After considering the whole of the evidence, together with the results of our own investigations and local inquiries, we are strongly of opinion that the only way in which this evil can be effectively dealt with is by placing tidal waters under the jurisdiction of some competent authority, and conferring on that authority power to prevent the taking of shellfish for human consumption from any position in which they are liable to risk of dangerous contamination, and to enforce restrictions as regards pollution, and as regards waters, foreshores, pits, ponds, beds and layings in which shellfish are fattened or stored, as and when required.

"For this purpose the powers of the authority must be elastic. The case of each river and estuary is a problem by itself, and it would not be practicable to fix by enactment any standard or standards which would be generally suitable to the widely different conditions of different cases. Moreover, as the conditions are shifting in character, it is necessary to provide some permanent machinery by which restrictions can be varied." [*Ib.* p. xxi., par. 39.]

CHAPTER XVIII.

SUPPLEMENTARY REPORTS ON LAND TREATMENT, &c.

The Commissioners concluded their Fourth Report with the following intimation :—

> "We have considered it desirable to publish, at this stage, the results and information which have been obtained by our own officers in regard to land treatment of sewage and methods of analysis ; but we shall defer reporting on these matters until our investigations, which are now in progress, in regard to other methods of sewage treatment, are completed."

The Reports by the Officers of the Commission (Dr. McGowan, Dr. Houston and Mr. Kershaw) were not issued until some nine months after the date of the Commissioners' Report, and were therefore not available in the preparation of the foregoing chapters. They will therefore be dealt with briefly in the ensuing pages, and referred to by footnotes in the earlier parts of the text which deal with the same subject matter.

The Reports in question, which, taken collectively, constitute the Fourth Volume of the Commissioners' Fourth Report, are as follows :—

Reports to the Commissioners by Dr. McGowan, Dr. Houston and Mr. Kershaw on Land Treatment of Sewage.

Part I. General Report.
Part II. Chemical Report, by Dr. G. McGowan.
Part III. Bacteriological Report, by Dr. A. C. Houston.
Part IV. Engineering and Practical Report, by Mr. G. B. Kershaw.
Part V. Report to the Commission by Dr. G. McGowan, Mr. R. B. Floris, A.I.C., and Mr. R. S. Finlow, B.Sc., on Methods of Chemical Analysis as applied to Sewage and Sewage Effluents.

The Officers first made a preliminary inspection of twenty-nine sewage farms, and collected a mass of general data with respect thereto. They subsequently selected for detailed observation eight farms having representative soils, namely:—

"Aldershot Camp. (Sand.)
Croydon, Beddington. (Gravelly loam.)
Nottingham and Cambridge. (Light loam.)
Rugby, High-level Farm. (Heavy loam.)
South Norwood and Leicester. (Clay.)
Altrincham. (Peaty soil and sand.)

"Luton, a typical instance of a chalk sewage farm, was also kept to some extent under observation. We also obtained some samples from the sewage farms of Worsley (partly peat, partly sand and gravel); Hemsworth (clayey soil); Derby County Asylum (stiff soil overlying red clay); Lindfield (clayey soil); Sandhurst (sandy soil); and Woking (Bagshot sand)."

The reporters go on to say:—

"Birmingham sewage farm is an exceptionally interesting one, treating as it does septic tank liquor; but its great size, the differences in the nature of the soil over the farm, and the important consideration of time, prevented us from including it in this scheme of work." [*Part I.* p. 6.]

General Conclusions.

The "General Conclusions" arrived at by Drs. McGowan and Houston and Mr. Kershaw, as the result of their investigations, comprise Section IX. of Part I. of the Report, and are as follows:—

"*Can Land Effluents be discharged into Drinking Water Streams?*

"The effluents from land processes of sewage treatment are not, from the bacteriological point of view, in a proper condition for discharge into drinking water streams.

"*Is the Bacterial Flora of Land Effluents characteristic of Sewage or of Soil?*

"The effluents from land possess a bacterial flora characteristic of sewage, and the microbes characteristic of soil (in

General Conclusions—*continued.*

the sense of being peculiarly abundant in soil) are *relativcly* absent from land effluents.

"*Is the Bacterial Flora of Sewage intrinsically modified by Land Treatment?*

"As a result of its treatment on land, and judged by the bacteriological tests employed in this investigation, sewage does not seemingly become modified in its biological character to any material extent. The bacteria, however, were reduced in number to a marked extent.

"*Results of Examination of Samples of Subsoil Water. Objection for Domestic Use to Wells sunk in polluted Soil.*

"The few samples of subsoil water collected in the neighbourhood of some of the sewage farms were usually found to be pure, both chemically and bacteriologically; but this, of course, must not be regarded as proving that wells sunk in such situations are safe for domestic use, or free from serious objection.*

"*Chemical and Biological Qualities of the River Water above the Effluent Outfalls.*

"The samples of water collected above the effluent outfalls, from the rivers into which the effluents from the several sewage farms are discharged, varied considerably. They would all have been condemned bacteriologically from the point of view of drinking water. Even from the point of view of non-drinking water streams their condition was not always satisfactory, either chemically or bacteriologically. Below the effluent outfalls the mixed liquid (river water and effluent) was, under the circumstances, usually not unsatisfactory. Generally speaking, the discharge of the effluents into the respective streams did not exercise any marked prejudicial effect on the water of the

* Two years' work by one of us on the chemical and biological qualities of the Chichester well waters showed that shallow wells sunk in polluted soil and subsoil may show, on searching bacteriological examination, unequivocal evidence of excremental and, therefore, potentially dangerous pollution.

General Conclusions—*continued.*

stream; indeed, the reverse was sometimes observed. There seems to be no reason to doubt that the effluents from properly managed sewage farms would, when discharged into non-polluted streams of relatively large volume, neither give rise to any nuisance, nor, so far as may be judged by rate of absorption of oxygen, prove injurious to fish.

"*Chemical and Biological Qualities of Storm Water and 'Street Washings.'*

"The samples of storm water* examined were almost invariably found to be most impure, both chemically and biologically. The samples of 'street washings' (separate system) were all impure biologically, notwithstanding that some of them were fairly pure organically from the chemical point of view and withstood the incubation test under laboratory conditions of experiment. The results, however, show that even when a street water is comparatively pure organically, it requires adequate settlement for grit, and, further, that the liquid may be very impure even after long-continued rain. The practical advantages of the separate system may be great, and doubtless storm overflows are necessary; but the fact that storm liquids may be so impure, both chemically and bacteriologically, is a point of considerable importance.

"*Basis for calculating Work done by Land.*

"In defining the work done by land in purifying sewage, the usual way of speaking of 'population per acre' is open to the objection that the volume of sewage per head per day may, and does, vary to a considerable extent at different places, and that a large volume of sewage per head of the population does not *always* mean a correspondingly weak sewage (*see* Rugby and Aldershot Camp). The best way, in our opinion, of recording the work done by land is to speak of the number of gallons of sewage (exclusive of storm

* As regards storm water, we draw here on the experience gained by the chemical and bacteriological examination of samples of storm water kindly sent us by Mr. Tatton from different places in the Mersey and Irwell watershed. These additional records are not given in much detail in this Report.

General Conclusions—*continued.*

water) treated per acre per twenty-four hours (*a*) on the 'working'* area, and (*b*) on the total irrigable area (working and 'resting' areas), together with notes as regards the organic strength and other characters of the sewage, the amount of storm water dealt with on the farm, and the depth and quality of the soil and subsoil.

"*Comparison of Terms.*

"The old terms 'intermittent downward filtration' and 'broad irrigation,' for the reasons previously stated, have been replaced by the terms 'land filtration' and 'surface irrigation.'

"*Can Land purify Sewage indefinitely? Disposal of Sludge.*

"Special attention must be directed to the length of time some of the farms have been in operation (five of them for over thirty years), and to the fact that some of them have disposed satisfactorily of their sludge on the farm during the whole period of their existence as sewage farms. Further, that most of them, year by year, have been called upon to treat an increasing volume of sewage without corresponding enlargement of their irrigable area. There seems no reason to doubt that, with proper management, land can purify sewage for a practically indefinite period.

"*Screening and Settling.*

"We are of opinion that sewage before it is applied to land should be efficiently screened and settled, unless it is already in a thoroughly disintegrated condition. Where the sewage is fresh, especially in the case of heavy clay soils used as surface irrigation farms, this is very necessary. Porous sandy soils, however, worked as filtration farms, can in some instances without apparent detriment receive sewage in the raw condition, and some observers consider that their efficiency is, if anything, increased thereby. But there is

* By "working" area is meant that portion of the total irrigable area which is actually being sewaged at one time.

GENERAL CONCLUSIONS—*continued.*

always the possibility of nuisance arising in this way. As regards chemically precipitated sewage and sewage treated by artificial processes antecedent to delivery on land, our data are insufficient to pronounce a decided opinion; but the views generally expressed by the witnesses called before the Commission are, no doubt, correct, namely, that land can deal directly with raw sewage, but it is better first to separate the solids mechanically; and, if the sewage of a large town has to be applied to a limited area of land, it may be advisable first to treat it chemically, or to pass it through bacteria beds.

"*Trade Refuse.*

"As regards trade refuse, the only two farms kept under observation where trade refuse was present in any quantity in the sewage, were Leicester (three-fourths domestic, one-fourth trade refuse), and Nottingham (four-sevenths domestic, three-sevenths trade refuse). The effluents from Nottingham were remarkably good; and those from Leicester fairly satisfactory, considering the available irrigable area, the nature of the soil, the method of treatment, and the volume of sewage being dealt with. Nevertheless, we do not assume from this that trade refuse (especially some kinds), if present beyond a certain proportion, may not seriously inhibit, if not prevent, the purification of sewage by treatment on land. On this point several of the witnesses before the Commission spoke somewhat strongly from personal knowledge and observation.

"*Are Sewage Farms a Source* (*direct or indirect*) *of Danger to Health? Questions relating to Stock and Farm Produce.*

"As regards the likelihood of sewage farms being dangerous to health, we can do no more than tentatively express the opinion that no convincing proof has yet been furnished of *direct* or wide-spread injury to health in the case of well-managed farms. It may be possible that the foul emanations from a badly managed or over-sewaged farm constitute an indirect source of danger to health by lowering the vitality of weakly and susceptible individuals.

"Further, even sentimental considerations are not to be ignored in this matter, and the alleged depreciation in the

General Conclusions—*continued.*

value of house property due to the proximity of sewage farms is, if true, a serious question. We are, therefore, of opinion that, subject to practical considerations, sewage farms in the neighbourhood of populous districts are liable to objection. In this connection the probably beneficial effect of a surrounding belt of shrubbery and trees has not, perhaps, been sufficiently recognised. As regards the produce from sewaged land, we are, on the whole, not in favour of sewage farms being utilised for the raising of crops for human consumption, however remote may appear the danger to health. But in respect of stock the case is different; and although we think it a wise precaution to keep cattle off recently sewaged land, we see no reasonable objection to stock being fed on the produce of antecedently sewaged land. But whenever there is a likelihood of the spores of B. Anthracis being present in the sewage, special precautions should certainly be taken as regards the grazing of animals on land 'treated' therewith.

"*Questions of Profit or Loss; Cropping, &c.*

"Although we are of opinion that sewage farms in general can never be expected to show a profit if interest on capital expenditure is included, the fact that in favourable seasons some of them can more than cover the working expenses is a point in favour of cropping in connection with the land treatment of sewage. Moreover, in our opinion, cropping makes for purification, given good management, a volume of sewage not out of proportion to the average area under sewage at one time, and a suitably large 'resting' area. We are not in favour of sewage farms being let; unless the irrigable area is very large, a tenant must sometimes be placed in the awkward position of having to choose between damaging a crop on the one hand, and purifying sewage imperfectly on the other.

"*Management of Sewage Farms.*

"It is impossible to lay too much stress on the importance of farms being well managed; but in this connection we desire to state that farm managers have usually a most difficult part to play, and no amount of care and attention

General Conclusions—*continued.*

will ever enable land, of any kind, to deal with a volume of sewage out of all proportion to the effective purifying area of the soil. We recommend that farm managers should be taught some simple test or tests to enable them to follow for themselves the operations of the land; that their instructions should be in writing, and should include a definite order to consider the farming results as quite secondary to 'turning out' uniformly a satisfactory effluent; that the statistics of the farm should be most carefully kept; and that, wherever possible, the flow of sewage and of storm water should be gauged throughout the year. In the case of all large sewage works, permanent provision should most certainly be made for recording, by some reliable method of gauging, the daily flow of sewage. Meteorological observations are also of importance. For example, a comparison between the curves of the air and of effluent temperatures may afford a useful indication of the amount of filtration that is taking place on the farm.

" *Questions of Temperature in relation to the Land Treatment of Sewage.*

"During the period of our investigations no opportunity occurred of watching the working of sewage farms during a prolonged period of exceptionally frosty weather. Nevertheless, on a number of occasions the weather was very cold, and the temperature of the air frequently sank below the freezing point. During these periods the ordinary working of the farm was not, so far as could be seen, seriously interfered with, and no lasting or marked deterioration of the effluents was observed. Although we are of opinion that temperature is a most important factor in purification, the range of temperature at which the bacteria concerned in sewage purification work is so wide that it can but seldom happen in this country that their vital activity is more than temporarily restrained. Surface irrigation farms suffer most in this respect, although, if the frost is sufficiently prolonged, filtration farms may also become affected. As explained elsewhere, the temperature of the effluents from surface irrigation farms varies almost in direct correspondence with the air temperature, whereas the temperature of the effluents from filtration farms is mainly governed by the

General Conclusions—*continued.*

temperature of the soil. The witnesses examined before the Commission expressed on this subject the most contrary views, but we agree with those who stated that frost and snow do not usually prevent, although they may retard, purification of sewage by treatment on land. Nevertheless, we think that frost, if exceptionally severe and prolonged, may prove a serious hindrance to *effective* purification, more especially on surface irrigation farms.

"*Nature of Crops best adapted for Sewage Farms.*

"We have already expressed the opinion that cropping may be advantageous. As regards the nature of the crops, cereals are, practically speaking, inadmissible on that portion of the irrigable area which at some time or other during the year's working of the farm is meant to be sewaged. The best crops are those which can be more or less continuously sewaged without detriment, *e.g.*, quickly-growing plants like rye-grass, mangold-wurzel, prickly comfrey, &c.

"*Storm Water and Fixed Overflows.*

"The question of storm water and fixed overflows is a most difficult one. Some of the witnesses examined before the Commission expressed the view that where storm water is to be dealt with on the land, the area of land required must be calculated upon the maximum volume of sewage that may be brought to the farm. Without in any way dissenting from this proposition in the abstract, it may be pointed out that if provision were made for treating at any one time sewage and storm water equal in amount to six times the dry weather flow of sewage, and if the basis for calculating the area required for purifying storm water were the same as for ordinary sewage, the surplus irrigable area on all farms would have to be increased to a serious extent. At first sight a feasible proposition would seem to be to reckon the extra area of irrigable land on the theoretical volume of liquid in excess of the dry weather flow capable, as the result of storms (if no overflows were in existence), of being brought to the works during the year. Then, if the 'resting' area of the total irrigable area of the farm were sufficiently large in relation to the 'working' area,

General Conclusions—*continued.*

any sudden fluctuations due to storm water could possibly be dealt with satisfactorily. But we do not know of any reliable way of calculating the yearly volume of storm water under the present unsatisfactory condition of matters as regards the absence, generally speaking, of apparatus to gauge by some efficient automatic method the daily flow of sewage throughout the year. As a matter of fact, on most farms considerable difficulty is experienced in dealing satisfactorily with the dry weather flow of sewage, and any large increase in the volume of sewage may mean the discharge into the river either of untreated sewage diluted with storm water, or of imperfectly purified effluents. The dry weather flow of sewage is reckoned on the flow during the whole twenty-four hours, but the difference between the maximum and minimum flow during the twenty-four hours is usually considerable. Hence, if a storm overflow be fixed at six times the average dry weather flow, it follows that during certain periods of the day a storm may cause the sewage to overflow with much less than an increase of six times the flow during these periods, and further, that the overflow might not come into operation during certain periods of the night, although the storm water may have increased the then flow ten or mere times. Yet the liquid in the former case must be more foul than in the latter case. Of course, it will be said that if the increase of flow during the night does not reach the overflow cill, there is no reason why it should not be treated on the farm. This may be true, but it must be remembered also that the ability of a farm uniformly to yield good effluents probably depends in no small degree on the *comparative* rest afforded the land during the night.

"Existing sewers are seldom large enough to carry off satisfactorily up to six times the dry weather flow of sewage, still less all the storm water in extreme cases, and if in the case of new sewerage schemes this were remedied, the cost would be serious, and the sewers would be large in relation to the dry weather flow of sewage, and disproportionately large in relation to the periods of minimum flow of sewage. Assuming, however, the possibility and practicability in all cases, of a volume equal to six times the dry weather flow being brought to the farm, we consider that the difficulty of

General Conclusions—*continued.*

treatment would be lessened by: (1) increasing the capacity of the settling tanks; (2) having a larger 'resting' area (*not*, however, at the expense of the 'working' area, but by enlarging the total irrigable area); and (3) in particular cases by laying out portions of the land in special ways, *e.g.*, lagoons, storm water filters, etc., which need not be described here, since these matters would be determined by the local conditions.

"The difficulty of treating storm water is largely an emergency one. As regards 1 and 2 above, by increasing the capacity of the settling tanks the effect of sudden fluctuations in the volume due to storm water would be in some measure controlled; the provision of a large 'resting' area would tend to prevent the normal 'working' area from being over-pressed during storms, as the former could be temporarily utilised to treat the increased volume of liquid. As regards (3), the subject is so wide, and depends so much on local circumstances, that it would be unwise to consider the matter further here.

"So far as our observations go, the effluents from sewage farms treating a large proportion of storm water do not deteriorate to any marked extent; they may even show a temporary improvement during periods of wet weather. But during wet weather the normal working of the farm may be seriously embarrassed, and it is difficult to estimate the ultimate effect of storm water on the quality of the effluents. Moreover, it must be remembered that a storm water effluent from land may be as pure or purer than an ordinary effluent, but that if the total bulk of the storm water effluent is several times in excess of the normal volume, the effect on the river water may be the reverse of satisfactory.

"In this connection we desire again to emphasise the fact that neither chemically nor bacteriologically is mere dilution synonymous with purification. Granting the impracticability of treating more than a certain proportion of storm water, it should be definitely understood that storm water is diluted, not purified, sewage.

"*Rate of Intermittency.*

"We have already expressed our opinion that the data available are insufficient to enable us to give any definite

GENERAL CONCLUSIONS—*continued.*

statement as to the best rate of intermittency either as regards filtration or surface irrigation farms. By 'rate of intermittency' is meant, of course, whether the alternate periods of working and resting the land should occur at short or long intervals. It is obvious that if the alternations be too frequent, the 'resting' area may not have time to recover its full purifying capacity before it is again sewaged, and, on the other hand, if the alternations be too infrequent, the 'working' area may be rendered sewage-sick; meanwhile the 'resting' area would be lying idle, long after it had recovered its purifying ability. A competent manager finds out by experience the best way of working the farm under his care; but it is desirable that the matter should be investigated experimentally, so as to enable certain general rules to be laid down for the preliminary guidance of persons responsible for the management of sewage farms.

"*Ratios of* (1) *Total Irrigable Area and Total Acreage; and* (2) '*Resting*' *and* '*Working*' *Areas of the Total Irrigable Area.*

"As regards the ratios between (1) the total irrigable area and the total acreage, and (2) the 'resting' and 'working' areas of the total irrigable area, we have previously pointed out at some length that the first consideration is to have (*a*) the 'working' area (*i.e.*, the area under sewage at one time) large enough to purify efficiently the whole volume of sewage which is being treated. Secondly, that (*b*) the 'resting' area should be greater in the case of surface irrigation farms than for filtration farms. The ratio of (*a*) to (*b*) at Beddington was 1 in 6, and at Nottingham 1 in 2. Without venturing to lay down any fixed rule, we think that a ratio of about 1 in 5 and about 1 in 3 as regards surface irrigation and filtration farms, respectively, is desirable; but the above statement is based on too limited a number of observations to be of much value. A large 'resting' area is especially necessary when much storm water is treated on the farm. Thirdly, that the surplus acreage (that is, the area representing the difference between the total irrigable area and the total acreage) should be ample. At Altrincham the surplus acreage was 53 and at Rugby 12 per cent. At the present time Altrincham is

General Conclusions—*continued.*

taking advantage of its relatively large surplus acreage, and is laying out a portion of it as an addition to the irrigable area.

"*Separate or Combined Sewerage System.*

"As regards the respective advantages and disadvantages of separate and of combined sewerage systems, reference must be made to Section II. (particulars relating to each of the eight sewage farms kept under detailed observation). We may, however, again point out that the liquid carried away by the separate system is not, so far as our few analyses go, in a fit state to be discharged without treatment into any river.

"*Suitability of Different Kinds of Soil.*

"The witnesses examined by the Commission as to suitability of different soils expressed very divergent views, some of them considering certain kinds of soil quite unsuitable, while others were of opinion that any kind of soil is capable of purifying sewage. Nearly all of them were agreed that light sandy loam overlying gravel and sand was the best type of soil for the purpose, while chalk, clay, peat and water-logged soils were regarded as either less suitable or as altogether unsuitable for sewage purification.

"Upon this point we may, at the risk of repetition, shortly summarise our own experience.

"A.—Filtration.

"1. Excellent results can be obtained from light loamy soil overlying a porous subsoil.

"2. A sandy soil and subsoil are also capable of yielding good results.

"3. The same may be said of a partially peaty soil overlying gravelly sand.

"4. Peat pure and simple is not well adapted for sewage purification.

"5. With regard to chalk, we can hardly speak with confidence, more data being required. The few (artificially obtained) effluents which we examined from a chalk farm had percolated *in about a minute and a half* through approximately three feet of chalk (from which the surface soil had

GENERAL CONCLUSIONS—*continued.*

been removed); in so doing they had undergone comparatively little purification organically, although the liquid in its passage dissolved out a large quantity of nitrate—the product, no doubt, of the oxidation of sewage matter * run on at a previous time. The purification would, of eourse, have been better had the surface soil also taken its part. But the above very rapid rate of filtration of sewage through the fissured chalk emphasises the necessity for carefully considering any possible connoction that may exist between a sewage farm on chalk and a water supply.

"B.—SURFACE IRRIGATION AND COMBINED SURFACE IRRIGATION AND FILTRATION FARMS.

"Heavy loam and clay soils, although not so well suited for sewage purification purposes, may, in our experience, yield fairly good effluents if the volumo of sewage treated per acre is relatively small.

"Thus, almost any kind of soil can be used for the purposes of sewage purification, provided, of course, that the volume is proportionate to the purifying capacity of the soil in question. In certain cases, no doubt, this volume would be so small as to render the particular method of treatment impracticable, but whero the line should be drawn it is difficult to say. The priee of land and other local eonditions must needs influence this question of practicability. We are far from advocating the treatment of sewage upon land which is, practically speaking, not well suited for the purpose, but this does not invalidate the truth of the proposition, that the matter is nearly always ono of *degree* of suitability, and seldom one of intrinsic disability. In reference to this, we would lay stress on the good quality of the best effluents obtained from all the eight sewage farms kept under detailed observation.

"*Volume of Sewage per Acre. Population per Acre.*

"A divergence also showed itself in the opinions of witnesses with respect to the question of population and of

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* Whether this nitrification had gone on solely in the surface soil or also in the chalk itself wo cannot say.

General Conclusions—*continued.*

volume of sewage allowable per acre. Some of them considered that the maximum limits should be 5,000 gallons per acre per 24 hours for an irrigation farm, and 30,000 gallons for a filtration farm. Allowing 40* gallons of sewage per head per day, this works out to 125 and 750 persons per acre respectively. On the basis of population, other witnesses gave 100 to 1,000 persons per acre as the working limits, the number varying with the process of treatment adopted, the nature of the soil, and other factors. Converted into volumes of sewage per head per 24 hours (at 40 gallons per head), this gives 4,000 to 40,000 gallons per acre.

"Others, again, suggested the following figures for population per acre:—

——	Crude sewage.	Precipitated or mechanically settled sewage.	Sewage after preliminary treatment on bacterial filters.
Surface irrigation ..	50 to 100	100 to 500	300 to 1,000 } persons per acre.
Filtration	75 to 150	200 to 500	400 to 1,000 } persons per acre.

"Again assuming 40 gallons of sewage per head per day, the above figures may be expressed thus:—

——	Gallons of crude sewage per acre direct on to land.	Gallons of sewage per acre after precipitation or settlement.	Gallons of sewage per acre after bacterial filters.
Surface irrigation ..	2,000 to 4,000	4,000 to 20,000	12,000 to 40,000
Filtration	3,000 to 6,000	8,000 to 20,000	16,000 to 40,000

* This figure of 40 gallons is taken because it was the average volume at the eight principal sewage farms kept under observation. According to some statistics collected recently by our colleague, Mr. Colin C. Frye, it is probably not far from the mean for towns and cities with a population of 10,000 to 100,000, and over, though much too high for small towns and villages. It is brought forward here for comparative calculations only.

General Conclusions—*continued.*

"Broadly speaking, therefore, the various witnesses examined placed the extremes at 50 persons or 2,000 gallons per acre per 24 hours, and 1,000 persons or 40,000 gallons per acre per 24 hours.

* * * * *

"*Summary.*

"The chief notes in this connection may be summarised as follows:—

"In the first place, the best kind of soil for filtration purposes (*e.g.*, light sandy loam overlying gravel and sand) can certainly purify to a remarkable extent, at the rate of 23,000 gallons of a strong mixed sewage per acre per 24 hours (*a*) at a given time; and over 10,000 gallons per acre per 24 hours (*b*) on the year's working of the total irrigable area (*see* Nottingham). Further, under (*a*) and (*b*) sets of conditions, over 100,000 and over 30,000 gallons respectively of a rather weak sewage can be purified to a fair although not to an altogether satisfactory extent (*see* Cambridge).

"Secondly, with soil less well suited for filtration purposes (*e.g.*, sand and partially peaty soil lying upon sand and gravel), from about 25,000 to 46,000 gallons of sewage per acre per 24 hours (*a*) at a given time; and from about 8,000 to 23,000 gallons per acre per 24 hours (*b*) on the year's working of the total irrigable area, can be treated so as to yield effluents fairly good, but, on the whole, not quite satisfactory (*see* Aldershot Camp and Altrincham).

"Thirdly, with soils passing from gravelly loam to heavy loam or clay, all being worked as combined surface irrigation and filtration farms, from about 12,000 to 57,000 gallons of sewage per acre per 24 hours (*a*) at a given time; and from about 4,000 to 9,000 gallons per acre per 24 hours (*b*) on the year's working of the total irrigable area can be treated so as to yield effluents moderately good, but still not altogether satisfactory (*see* Beddington, Rugby, Leicester, and South Norwood).

"To summarise all our results within the limits of a few sentences is impossible, but we may say in conclusion, and speaking in general terms, that we doubt whether even the most suitable kind of soil worked as a filtration farm should

General Conclusions—*continued.*

be called upon to treat more than 30,000 to 60,000 gallons per acre per 24 hours at a given time (750 to 1,500 persons per acre); or more than 10,000 to 20,000 gallons per acre per 24 hours, calculated on the total irrigable area (250 to 500 persons per acre). Further, that soil not well suited for purification purposes, worked as a surface irrigation or as a combined surface irrigation and filtration farm, should not be called upon to treat more than 5,000 to 10,000 gallons per acre per 24 hours at a given time (125 to 250 persons per acre); or more than 1,000 to 2,000 gallons per acre per 24 hours, calculated on the total irrigable area (25 to 50 persons per acre). It is doubtful if the *very worst* kinds of soil aro capable of dealing quite satisfactorily even with this relatively small volume of sewage. The population per acre is calculated on 40 gallons of sewage per head per day. It is here assumed that the sewage is of medium strength, and is mechanically settled before going on to the land.

"Comparing the above figures with the volume of sewage capable of being treated by artificial processes, we note that the witnesses examined by the Commission generally expressed the following opinion:—

"*Contact Beds.*—750,000 gallons per acre per 24 hours, allowing for periods of rest, but not for secondary treatment. Allowing one acre of secondary bed for every two acres of primary bed, about 500,000 gallons per acre per 24 hours could according to this view be finally treated. It is assumed always that the sewage has been previously treated either by chemical precipitation, or by subsidence in settling tanks, or in a septic tank.

"*Continuous Filters.*—About 484,000 to 2,904,000 (4,840,000 according to one witness) gallons per acre per 24 hours. Previous treatment by chemical precipitation, or subsidence in settling tanks, or in a septic tank is assumed.

"Apart from the question of the quality of the effluents, it is obvious that, generally speaking, a larger volume of sewage can be treated by artificial bacteria bed processes than by land.

General Conclusions—*continued.*

"Management of Sewage Farms.

"There can be no doubt that even the best of sewage farms, with the most suitable soil, will under continued bad management fail to turn out a satisfactory effluent.

"The question of whether or not a particular farm is going to purify the sewage efficiently depends mainly upon the manager, assuming, of course, that the farm has been properly laid out in the first instance, that it has a reasonable volume of sewage to treat, and that the manager has (within certain limits) a free hand in the supervision of sewaging operations. The fact, however, must not be lost sight of that he has often a most difficult post to fill, especially with regard to the crops. The effectual purification of sewage, even with suitable land, can only be accomplished when the farming operations are relegated to the background and the production of a good effluent considered of primary importance. On the other hand, the manager knows that the crops will probably form an important item in his receipts at the end of the year, and he not unnaturally wishes it to appear that the farm is being worked economically under his supervision. Hence there is a temptation to grow remunerative crops, *e.g.*, cereals, that cannot be sewaged (at all events for the greater part of the year), or to refrain from the further sewaging of crops which may be damaged thereby; meanwhile the land which is under sewage must needs yield, owing to the lack of rest, increasingly unsatisfactory effluents. There may of course be some farms where the large area at command in proportion to the volume of sewage to be "treated" renders the growing of grain crops justifiable, but these are exceptions to the general rule. Land is usually too expensive in the immediate vicinity of towns to allow of this, and the tendency is to take too little rather than too much land for a sewage farm.

"Speaking generally, large farms are better managed than small ones, this being in great measure due to the fact that the salary attached to the latter does not always offer sufficient inducement to a competent man to undertake the duties. In many instances there are small districts fairly near together, each with its own sewage farm. In such cases

General Conclusions—*continued.*

a combined scheme would appear to be advantageous; by adopting this course an adequate salary could be paid so as to secure an efficient manager, while the annual cost of treating the sewage would also be lessened. On the other hand, it is possible to have a sewage farm so large as in a sense to be unwieldy.

"It seems desirable that managers should employ day by day some simple chemical test or tests to enable them to follow the results of the working of the farm to the best advantage. It is probable that attention to this point would do much to foster the desire on their part to turn out the best effluent possible, at the expense, if necessary, of the crops. This question is raised quite apart from the larger one of appointing a qualified chemist in connection with all large sewage disposal works.

"In the case of a new farm it would seem advisable, if practicable, that the prospective manager should be on the spot while the works were being carried out, as he would thereby obtain an insight into details which otherwise it might take him some time to discover (*e.g.*, the nature of the soil and subsoil on different parts of the farm, as disclosed by drainage operations). In connection with this, it may be remarked that the soil and subsoil are rarely uniform in nature throughout a farm, and that therefore the various plots cannot all take the same quantity of sewage.

"We are unable to recommend the abandonment of farming operations even in connection with filtration sewage farms, because, if intelligently pursued, they make for profit with increased efficiency of the land. The farming operations, however, should always be under the control of the authorities responsible for the proper working of the farm, and the manager should receive written and explicit directions to regard the crops as of secondary importance to the uniform and satisfactory purification of the sewage.

"It would be invidious to attempt to arrange in order of the excellence of the management the various farms, which by the courtesy of the local authorities and their officers we have been enabled to keep under observation, but Nottingham Sewage Farm cannot be passed over without special comment. There can be no question that here the excellent

management of the farm largely contributed to the remarkably good quality of the effluents." [*Part I.*, pp. 105 *et seq.*]

Standards of Purity.

The question of standards of purity does not come up in the "General Conclusions," but is dealt with by Dr. McGowan and Dr. Houston in their detailed reports.

With regard to chemical standards of purity Dr. McGowan makes the following observation:—

> "The question of what considerations should weigh most iu recommending a working chemical standard of purity for sewage effluents is a very difficult one." [*Part II.*, p. 325.]

After reciting the various standards which have been adopted or proposed by different authorities, he goes on to say:—

> "It seems, therefore, reasonable to suggest that, if any chemical standard of purity is to be ultimately proposed by the Commission, it should be one depending, at all events partially, upon the rate at which oxygen is taken up; all the more since the diminution of the dissolved oxygen in brook and river waters by effluents is one of the main things which we have actually to guard against." [*Ib.*, p. 327.]
>
> "Without making any definite or final statement on the subject at present, we think it would probably be found that any effluent which did not, within the twenty-four hours after drawing, take up more than about 3 to 4 c.c. of oxygen per litre (when kept in a full bottle at, say, 18° C., or 65° F.), would be found to be chemically satisfactory. The test might have to be taken in conjunction with the permanganate 'oxygen absorbed' test, to provide against the (unlikely) contingency of an effluent being a sterilized one; and in the present state of our knowledge, it might also be advisable to safeguard it further as regards a maximum of nitrogenous organic matter to be allowed in any effluent at any time (measured, say, by the albuminoid nitrogen), though this additional precaution might in the end be found unnecessary.
>
> "We think there can be no doubt that, if it could be satisfactorily and easily worked out in practice, a standard based upon the above principles would deal equably between effluents from strong and weak sewages, not favouring the one at the expense of the other." [*Ib.*, p. 328.]

STANDARDS OF PURITY—*continued.*

Dr. Houston in his report points out that *in the case of drinking-water streams* the bacteriological examination is of more importance than the chemical; and, while recommending as a "counsel of perfection" the "complete sterilization of sewage effluents," suggests as a "practicable" standard "partial sterilization (absence of B. coli from 1 c.c. of the effluent)." [*Part III.*, p. 13.]

"In the case of *non-drinking water streams*," he adds, "the bacteriological standard is of secondary importance, but it may prove valuable as an adjunct to the chemical standard." [*Ib.*]

> "The provisional standards* suggested for comparative and working purposes, to apply to non-drinking water streams, are as follows:—

Total number of bacteria	Gelatine at 20° C., less than 100,000 per c.c.	
	Agar at 37° C., less than 10,000 per c.c.	
B. coli, less than 1,000 per c.c.		
B. enteritidis sporogenes test . . .		Negative results with 0·1 c.c.
'Gas' test (twenty-four hours at 20° C.)		
Indol test (five days at 37° C.). . .		Negative results with 0·001 c.c."
Neutral-red-broth test (two days at 37° C.)		
Bile-salt broth test (two days at 37° C.) .		
Litmus milk (modified) test (two days at 37° C.).		[*Ib.*, p. 14.]

Later on in his report Dr. Houston deals with the question of storm water, which he regards as being "as potentially dangerous to health as normal crude sewage." He recognises the impossibility of treating the whole flow of sewage during storms, and adds that:—

> "If, for practical reasons, it is necessary to discharge liquids of this kind in the untreated condition into the watercourses, it would seem to be illogical to enforce the adoption of drastic standards of purity in connection with sewage effluents." [*Ib.*, p. 187.]

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* These are primary standards; my secondary standards are arrived at by rendering the primary standards ten times more lenient. *It must be definitely understood that these standards are not suggested in an administrative sense; they are merely arbitrary, and designed solely for comparative purposes.* [Part III., p. 14.]

Methods of Chemical Analysis.

Part V. of the volume under consideration describes the methods adopted by Dr. McGowan and his assistants for collecting, preserving, and analysing samples of sewago and effluent, and preparing the necessary standard solutions. Some alternative modes of analysis are also described, and various sources of error indicated.

Dr. McGowan calls attention to the discrepancies produced by minor variations in procedure, and expresses the wish that chemists could arrive at some general agreement as to methods. [*Part V.*, p. 14.]

His results, so far as they relate to weight, are expressed in parts per 100,000, and those referring to dissolved gases in parts per 1,000 by volumo. He goes on to say:—

> "It would be a great convenience if this mode of expressing results were generally agreed to and adopted by chemists throughout the country and by managers of sewage farms or works, as such a course would greatly facilitate the reading and comparison of reports." [*Ib.* p. 9.]

CHAPTER XIX.

THE OUTLOOK.

The Commissioners' Third Report concludes with a statement concerning the progress of their inquiry, and the work which still remained to be done.

"General Position of our Inquiry.

"77. In conclusion, we think it may be desirable briefly to explain the position of our investigations.

"78. At the commencement of our inquiry we devoted considerable attention to general questions relating to the chemical and bacteriological analysis of sewage, and sewage effluents.

"The methods of bacteriological analysis which we have adopted, are explained in a paper by Dr. Houston, which we presented with our second report.

"A paper is now in preparation by Dr. McGowan in regard to chemical analysis, which will contain a detailed account of the work which has been done under our direction, with a view of settling the value of the different methods of analysing sewage effluents.

"79. We have completed a systematic* investigation of tho land treatment of sewage on farms of different kinds of soil.

"This investigation has extended over a period of two years, and has embraced the bacteriological, chemical, and engineering aspects of this method of disposing of sewage.

"80. We are now making a similar investigation of artificial processes of various kinds at about thirty distinct places. This investigation will, we hope, be completed in about a year.

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* The general results of this investigation are given in the preceding Chapter.

General Position of our Inquiry—*continued.*

"In addition, certain authorities are, in conjunction with us, making similar systematic observations in regard to a number of artificial processes.

"When these results have been collected, we shall endeavour, in compliance with the instructions contained in the second part of our terms of reference, to report on the different methods of treating sewage in the same and in dissimilar sets of circumstances.

"81. In the meantime, we are taking evidence as to the discharge of sewage, sewage effluents, and manufacturing effluents into tidal waters. The importance of this subject as regards the contamination of shellfish has recently come into prominence. It is, indeed, a matter of great importance from the point of view both of public health and the fishing industries.*

"82. We are also continuing the investigations which we referred to in our interim report, for the purpose of ascertaining whether it is practicable to destroy these micro-organisms which are common to sewage effluents, and which may be dangerous, if the effluent flows into a river from which water for drinking is obtained, and we are generally considering what measures may be desirable to lessen dangers so arising.

"83. Subsequently, we propose to consider the methods available for the satisfactory disposal of manufacturing effluents when not mixed with ordinary sewage." [*Third Report*, p. xxix.]

The Adoption of Rules.

It will be remembered that the terms of reference to the Commissioners included a direction to consider and report

"if more than one method (of treating sewage) may be so adopted, by what rules in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, should the particular method of treatment and disposal to be adopted be determined." [*Interim Report*, p. iii.]

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* This question is dealt with in the Commissioners' Fourth Report. See p. 300.

The Adoption of Rules—*continued.*

Of all the important questions the solution of which constitutes the work of the Commissioners, there is none more weighty than that as to the desirability or otherwise of tying the hands of the Local Government Board, and through them those of local authorities, by the adoption of hard-and-fast rules. If there is one point more than another which has been brought out by the inquiry it is the tremendous complexity of the subject with which the Commissioners have to deal and the incomplete state of our knowledge concerning it. Any prospect, therefore, that a binding set of rules would be drawn up would be regarded with the gravest apprehension by those who are charged with the purification of sewage, and not less by those whose duty it is to enforce the law relating thereto. This observation involves no disparagement of the ability of the present Commissioners, but merely recognizes the fact that it is out of their power to forecast the additions which the near future may make to our knowledge of sewage and its purification.

Where there is still so much to learn, the only safe school is that of experience, and unless public bodies are left free to adopt any process which offers a reasonable prospect of success, the possibility of improvement in existing methods will be severely curtailed.

It should not be overlooked that well-nigh the whole of our present knowledge concerning the action of bacteria on sewage in the mass has been gained from experiments carried out by local governing bodies, among which it is not invidious to mention those of London, Exeter, Sutton, Manchester, and Leeds. The gain which the country at large has derived from their work can hardly be overestimated. It is, perhaps, too much to expect that enterprise of this kind shall be encouraged, but it is surely reasonable to hope that in future a town which, by its own efforts and at the expense of the current rates has found a way out of its difficulties, shall not be deprived of the fruits of its labours simply because the method which these indicate did not come before the last Royal Commission which dealt with the subject.

The question of the necessity or desirability of rules is only referred to incidentally in the evidence. The only argument which the writer has ever heard in favour of their adoption is that, where they are known to exist, they save the Local Government Board the trouble of rejecting a number of unsatisfactory schemes which might otherwise be submitted to

THE ADOPTION OF RULES—*continued.*

them. The advantage thus gained is after all more apparent than real, for, in the absence of definite rules, those who have to do with sewage disposal know pretty well what the Board are accustomed to accept or reject. There is little doubt that the rules which have already been adopted by the Board to govern the design of sewage disposal works, and to which as general statements of what is desirable *in ordinary cases*, little or no exception can be taken, have done great harm by fostering the idea that the design of such works is a mere matter of arithmetic, and have thus made it easy for any man possessed of a fair knowledge of construction, and the ability to make a decent drawing, to pose as an engineer, and draw up a scheme which did not by any means meet the requirements of the case, but to which it was difficult for the Board to take exception, since it complied with the rules which they themselves had laid down.

Even if our knowledge of the subject had reached such a pitch that it could safely be said that nothing remained to be learnt, the question presents so many variables that it passes the wit of man to evolve a set of rules which will apply even approximately to every case. The adoption of rules to regulato the design or capacity of works is open to precisely the same objection which has been urged by so many witnesses against the laying down of a legal standard of purity; for if the limits established are such as to be safe in all cases, they will of necessity be far too stringent for some. As Mr. Killick has well pointed out, "you cannot go faster than you will take the public" [6049], and arbitrary rules will always be evaded. It would be easy to quote instances in which the rules imposed by the Local Government Board have been found so onerous that local authorities have been driven to dispense with loans, and pay for their schemes out of revenue. In some cases the work has been well conceived and well executed; but only too often the limitation of means, where the money has had to be taken out of the rates, has led to the adoption of patchwork schemes; and when, through the failure of these, the council has been compelled to go into the matter on a proper basis, the district has been so impoverished that it has been a serious hardship to find the necessary money.

It is well known that local authorities north of the Tweed are given a much freer hand in disposing of their sewage than those in this country, and it is hard to believe that English councils

The Adoption of Rules—*continued.*

aro less competent to deal with matters of the kind than corresponding authorities in Scotland.

One cannot help feeling that the Local Government Board place themselves in a very invidious position by assuming the responsibility of prescribing what methods may or may not bo used, or what provision should be made in particular cases. Their inspectors, able and conscientions as they are, cannot possibly have that intimate knowledge of local circumstances which would alone warrant them in doing so; nor, as a rule, are they given time or opportunity to acquire it.

In thus deprecating the establishment of a rigid set of rules, the writer has no wish to take exception to the control of public expenditure now exercised by the Board. Few wonld grudge the pockets of the ratepayers their second line of defence, or complain if local authorities, wishing to pledge the credit of their successors, are called upon to justify the proposed expenditure, and to produce reasonable proof that the intended works will serve their purpose.

Tho view of the matter taken by Mr. Strachan seems to be a sound and reasonable one:—

> "I do think it is very desirable that they" (the big towns) "should be allowed money to carry out whatever they can get responsible men to advise them is likely to lead to sncccss, without being hampered by conditions that they shall make a complete solution of their problem." [7633.]

As the attitude of the Local Government Board has been strongly criticised in some quarters, and tho Board have been suspected of a disposition to model their procedure on that of Procrustes, it is only fair to call attention to Mr. Adrian's statement with reference to the rules relating to land:—

> "Their application is subject to special consideration of the actual circumstances of each case. The Board do not look upon themselves as tied to a uniform and strict observance of the scale." [108.]

It may not be amiss to point out that much misunderstanding exists as to tho functions and dnties of the Local Government Board, and one frequently finds anthorities under the impression that by sanctioning a scheme tho Board gnarantee its success. This is, of course, not so, and in certain cases tho Board havo explicitly pointed out that tho responsibility for tho scheme

THE ADOPTION OF RULES—*continued.*

rests with the local authority. It would save a great deal of misconception if this were done in all cases.

If local authorities are to be held responsible for the prevention of the pollution of rivers by their sewage, it is intelligible; it is intelligible also if they are to be called upon to deal with their sewage in a prescribed way; but to tie their hands as to the methods which they use, and at the same time to hold them responsible for the results, is, to say the least, anomalous.

The protection of our rivers from pollution does not depend on the existence of rules calling for a given ratio between flow and filter capacity, nor yet on the provision of a certain area of land; for the men who are charged with the sanitary administration of our towns and villages are not, as a rule, lacking in public spirit or a sense of duty, and for the laggards the powers of the law with respect to rivers pollution are always available.

While we should all like, if possible, to be guided by counsels of perfection, we have to consider what it is practicable to accomplish, having regard to the inherent difficulties of the problem and the other pressing duties with which local authorities are charged. The easier the task of sewage purification can be made for them, and the freer their hands are left as to the mode in which they perform it, the sooner will our rivers and streams be restored to the condition which is ardently desired by all.

APPENDIX A.

Brief Summary of Events Referred to in the Evidence and Elsewhere.

1831 Board of Health (provisional) appointed in view of cholera epidemic.

1840 Select Committee of House of Commons appointed "to inquire into the circumstances affecting the health of the inhabitants of large towns, with a view to improved sanitary arrangements for their benefit." Reported June 17th.

1843 Royal Commission appointed "to inquire into the present state of large towns and populous districts."

1844 Royal Commission, First Report.

1845 Royal Commission, Second and Final Report.

1847 Towns Improvement Clauses Act.

1847 Metropolitan Sanitary Commission appointed and made First Report.

1848 Metropolitan Sanitary Commission, Second Report.

1848 Metropolitan Sanitary Commission, Third and Final Report.

1848 Public Health Act.

1848 Nuisances Removal and Diseases Prevention Act.

1848 Metropolitan Commissioners of Sewers appointed.

1848 General Board of Health established.

1854 General Board of Health reconstituted.

1857 Royal Commission appointed to inquire as to the best mode of distributing the sewage of towns.
1858 Local Government Act.
1858 General Board of Health abolished.
1858 Royal Commission, Preliminary Report.
1861 Royal Commission, Second Report.
1861 Local Government (Amending) Act.
1864 Report of Committee on plans for dealing with the sewage of the Metropolis.
1865 Royal Commission as to the best mode of distributing sewage, Third Report.
1865 Rivers Pollution Commission appointed.
1866 Sanitary Act.
1868 Rivers Pollution Commission revoked. New Rivers Pollution Commission issued.
1869 Royal Sanitary Commission appointed.
1870 Rivers Pollution Commission, First Report.
1870 Rivers Pollution Commission, Second Report.
1871 Rivers Pollution Commission, Third Report.
1871 Royal Sanitary Commission reported.
1871 Local Government Board established.
1872 Rivers Pollution Commission, Fourth Report.
1872 Rivers Pollution Commission, Fifth Report.
1872 Public Health Act.
1874 Rivers Pollution Commission, Sixth and Final Report.
1875 Public Health (Amending) Act.
1876 Pollution of Rivers Act.
1882 Commission appointed to inquire into the effects of the discharge of the sewage of the Metropolis into the River Thames.
1884 Results of Warington's Researches in Nitrification published.
1884 Metropolitan Sewage Commission, First Report.
1885 Metropolitan Sewage Commission, Second and Final Report.

1886 Report from Select Committee on Pollution of River Lea.
1887 Massachusetts experiments begun.
1888 County Councils established.
1891 Mr. Scott Moncrieff's experiments begun.
1892 Experimental filters laid down at Northern Outfall at Barking.
1893 Acre filter laid down at Northern Outfall.
1894 Mr. Cameron laid down first experimental septic tank at Exeter.
1895 London County Council published Main Drainage Committee's Report.
1896 First coarse bacteria bed laid down at Sutton.
1897, **Nov. 23, 24, 25.** Local Government Board Inquiry at Exeter, *re* Sewage Disposal.
1898, **May 7.** Royal Commission on Sewage Disposal appointed.
1898, **June.** Exeter scheme sanctioned.
1899, **Jan. 12, 13, April 29,** and **May 1.** Local Government Board Inquiry at Manchester.
1901, **July.** Royal Commission, Interim Report.
1902, **July.** Royal Commission, Second Report.
1903, **Mar.** Royal Commission, Third Report.
1903, **Dec.** Royal Commission, Fourth Report.

APPENDIX B.

REPORTS BY PRESENT COMMISSION.

			s.	d.
Interim Report, 12th July, 1901		[Cd. 685]..	0	2
,,	Vol. II. Evidence. 1902.	[Cd. 686]..	4	6
,,	Vol. III. Appendices. 1902.	[Cd. 686—I.]..	14	9
Second Report, 1902. (Chemical and Bacteriological Reports by Officers of Commission.)		[Cd. 1178]..	4	10
Third Report, 2nd March, 1903.	1. Trade Effluents. 2. A new Central Authority.	[Cd. 1486]..	0	4½
,,	Vol. II. Evidence. 1903.	[Cd. 1487]..	2	8
Fourth Report, 28th December, 1903.	(Pollution of Tidal Waters, with Special Reference to Contamination of Shellfish.)	[Cd. 1883]..	0	4½
,,	Vol. II. Evidence. 1904.	[Cd. 1884]..	6	6
,,	Vol. III. Reports by Dr. Houston on Bacteriological Investigations, Correspondence with Foreign Countries as to Shellfish. 1904.	[Cd. 1885]..	10	10

		s.	d.
Fourth Report,	Vol. IV., Part I. General Report by Officers of Commission on Land Treatment. 1904. [Cd. 1886]..	3	9
,,	Vol. IV., Part II. Chemical Report by Dr. McGowan. 1904. [Cd. 1886—I.]..	9	7
,,	Vol. IV., Part III. Bacteriological Report by Dr. Houston. 1904. [Cd. 1886—II.]..	5	3
,,	Vol. IV., Part IV. Engineering and Practical Report by Mr. Kershaw. 1904. [Cd. 1886—III.]..	11	0
,,	Vol. IV., Part V. Report by Dr. McGowan, Mr. R. B. Floris, and Mr. R. S. Finlow, on Methods of Chemical Analysis as applied to Sewage and Sewage Effluents. 1904. [Cd. 1886—IV.]..	0	7

INDEX TO WITNESSES AND OTHERS REFERRED TO.

N.B.—The writer, following the practice of the Commissioners, has referred to the witnesses merely by their surnames, except where it has been necessary to distinguish two witnesses of the same name. Their initials and qualifications are given in the Index. He must, in justice to the witnesses from whom he has quoted, point out how impossible it is to give in small compass any adequate representation of the tenor of their evidence as a whole. If, therefore, some of the answers cited seem bald, or even inconsistent, he asks his readers to accept his assurance that a reference to the context would place them in a very different light. While, however, the evidence of individual witnesses has necessarily suffered from the compression to which it has been subjected, the writer has endeavoured to make the compilation, taken as a whole, an intelligible and connected *précis* of the Commissioners' Reports.

SUBJECT INDEX.

* Now "Royal Sanitary Institute."

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